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Dissertation

THE ACQUISITION OF THE CONCEPT OF FRICTION

Submitted by
Ralph Benjamin DeLano
(A.M. Middlebury College)
1915

In partial fulfillment of requirements for the
degree of Doctor of Education

1942

Committee on Acceptance

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Norton A. Kent, Professor of Physics
Donald D. Durrell, Professor of Education
J.Wendell Yeo, Assistant Professor of Education

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[1] Rogers D. Rusk, How to Teach Physics, J.B. Lippincott Co., Philadelphia, 1923.

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CHAPTER I

INTRODUCTION

Bulletin No. 6,[1] 1938, of the United States Office of Education gives the following percentage enrollment of high school students enrolled in physics:

1890 - 22%
1895 - 23%
1900 - 20%
1910 - 15%
1920 - 10%
1934 - 6%

There are several reasons why enrollment in physics should be increasing rather than decreasing.

1. Physics is our most fundamental scientific subject. This concept is well illustrated by H. E. Brown[2] in the following:

"Man is supposed to have passed through several epochs in the march of progress from savagery to civilization....The present epoch is called the 'Age of Mechanical Power', and is considered by many as more important than the epochs which followed the introduction of the use of fire, the domestication of animals, the cultivation of fruits and grains, the discovery of iron, or even the invention of the printing press. Until the dawn of the 'Age of Mechanical Power", man's capacity for work and production was limited by his own strength plus that of domestic animals. Mechanical power in the short interval of a little more

---

[1] Carl a Jessen and Lester B. Herlihy, Offerings and Registrations in High School Subjects, U.S. Office of Education, Bulletin Number 8, Government Printing Office, Washington,1938, p.28-29.

[2] H. Emmett Brown, "The Plight of High School Physics", School Science and Mathematics, XL, Number 9(December,1940),p.816-819.

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than a century, by transferring reliance from animate to inanimate energy, has revolutionized the whole environment of human life by enabling man to utilize the energy and materials of his environment more effectively....Physics shows what the machine does, and explains how it works."

2. Complicated devices, developed as a result of the study of physics, are being used by more people today than at any other time in the history of our country. Some of these inventions are mentioned in an article in School Science and Mathematics.[1] " Since the beginning of the present century six major industries have burgeoned into national importance. These are the telephone, the automobile, the airplane, the motion picture, rayon, and radio industries. They employ both millions of workers and millions of dollars of capital. Their development has profoundly affected the character of American life. And yet any examination of texts and courses of study will reveal that we physics teachers have been content merely to discuss the principles involved in those five (of the six) industries to the development of which the field of physics has made a major contribution."

3. Some of these devices, when improperly used, cause death to our own citizens. Much of this unnecessary loss of life can be prevented by a knowledge of the laws of physics. According to the Massachusetts Safety Council,[2] the record in the United States for 1939 was 32,600 deaths caused by motor vehicle traffic.

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[1] H. Emmett Brown, op. cit.,p.816.
[2] Lewis E. MacBrayne, Accidents Which Happen in the Model Home, Massachusetts Safety Council, Boston, 1940,p.3.

In that same year, 1,150,000 persons received non-fatal injuries in motor vehicle accidents. C. E. Dull[1] states that a knowledge of the car's mechanism increases the comfort and the safety of the driver and his passengers.

4. The defense of our country in time of war depends in part upon our knowledge of physics. Without a knowledge of physics we would lack the machines necessary to carry on the war. D.Wharton[2] states that the engineers run the greatest show in the army. He says that they block roads against tanks, build bridges, make mechanized warfare possible, produce maps, lay antitank mines, operate railroads, and camouflage important places and equipment. The evacuation of Dunkirk and the destruction of Belgium's great Fort Eben Emael were made possible by the army engineers, according to D. Wharton. "Applied physics is engineering, but the connection between the two is rarely made by the average person", says H. Emmett Brown.[3]

5. Scientific hobbies of men, women, boys and girls indicate a natural interest, not due to necessity of use, in the laws of physics. Photography is probably one of the most popular hobbies. There are three large camera clubs in Boston: the Boston Camera Club, the 35 mm. Club, and B.Y.M.C.A. Club. The Boston Center for Adult Education[4] has been giving a course entitled "Taking Pictures for Fun" for a number of years. Two instructors are employed. No degree

---

[1] Charles E. Dull, Modern Physics, H. Holt and Company, New York, 1929, p.703.

[2] Don Wharton, "Engineers to the Front", Reader's Digest, 39, Number 236 (December, 1941), p.85-88.

[3] H. Emmett Brown, "The Plight of High School Physics", School Science and Mathematics, XLI, Number 2 (February, 1941), p.172-173.

[4] Catalogue, New Wartime Courses, Boston Center for Adult Education, Boston, Spring, 1942, p.29.

credit is given.

The methods which are commonly employed in most of our schools seem logical enough. They should accomplish results. The data in Bulletin No. 6,[1] U. S. Office of Education, however, give evidence of the fact that the expected results have not been attained.

Despite the scintillating chiaroscuro or flashing rapidity of change in science, there are two transcendents which permeate nearly all topics. Friction is one of these. Wherever we find motion, friction usually has some effect upon it. The study of physics is largely a study of matter in motion. Energy may be considered as another transcendent. Dr. Bless[2] states that physics may be defined as the study of energy. The transcendent friction was selected because it is comparatively easy to define and understand. In addition to being inherent in practically all matter in motion, friction touches, to a great extent, the experiences of children of Grades VII to XII.

---

1. Carl a Jessen and Lester B. Herlihy, op. cit., p.28.

2. A.A. Bless, "The Teaching of Physics", School Science and Mathematics, XXVIII, Number 5 (May, 1928), p.486.

TEST ON FRICTION

Prepared by

RALPH B. DELANO

Memorial High School, Boston, Massachusetts

Form A

Your name .... Boy .... Girl ....

Name of school .... City ....

Your age at last birthday .... When were you born ....
Month Day Year

Date .... Teacher's name ....

Write below the name of the science (nature study, general science, biology, science I, science II, physics, chemistry, etc.) you studied in each grade. If you did not study a science in any of the grades listed below, write "No Science" after that particular grade.

Grade V ....
Grade VI ....
Grade VII ....
Grade VIII ....
Grade IX ....
Grade X ....
Grade XI ....
Grade XII ....

In what particular application of science are you most interested? Check one of the following scientific devices or add the name of some practical machine which appeals to you.

1. Radio
2. Automobile
3. Airplane
4. Camera
5. Engines
6. ....

DIRECTIONS FOR MARKING THE TEST

Put an X, in the brackets, before the most nearly correct completion word, statement, or answer. Use only one X for each numbered question. Do not write anything or mark the test in any other way.

Example Number 1

1. A circle is

[ ] square.
[X] round.
[ ] rectangular.
[ ] longer than it is wide.

Example Number 2

2. If a sidewalk is covered with one of the following substances, on which material would you be most likely to slip?

[ ] Sand.
[ ] Ashes.
[ ] Dirt.
[X] Ice.

Go through the booklet and answer first the questions which you can answer most easily. Then go back and try to answer as many of the other questions as you can. Keep working until you are told to stop. WORK RAPIDLY.

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TEST ON FRICTION

1 When wearing smooth-soled rubbers, there would be less danger from slipping when the sidewalk is

[ ] covered with ice.
[ ] covered with water.
[ ] covered with mud.
[ ] perfectly dry.

2. It is a help when skating to have

[ ] the surface of the ice very smooth.
[ ] the surface of the ice very rough.
[ ] snow on the ice.
[ ] the runners of the skates rough.

3. The ridges on a rope

[ ] make it easier to pull.
[ ] make it harder to pull.
[ ] have no effect on the force needed.
[ ] increase the force required to keep it from slipping.

4. When the wheel of an automobile runs off the pavement into the sand, it tends to

[ ] move faster.
[ ] move more slowly.
[ ] move at the same speed.
[ ] pull one side of the car forward.

5. A machine belt works better if it is composed of material with a

[ ] very smooth surface.
[ ] very rough surface.
[ ] surface which is neither very smooth or very rough.
[ ] damp surface.

6. The ridges usually found near the heads of nails

[ ] make the nails stronger.
[ ] make the nails drive more easily.
[ ] keep the nails from rolling.
[ ] increase the force needed to pull out the nails.

7. A force is something we can easily measure with a

[ ] ruler.
[ ] watch.
[ ] quart cup.
[ ] balance.

8. If the brakes of an automobile are set so that the wheels can not rotate, the force required to move the car is

[ ] increased.
[ ] decreased.
[ ] unchanged.
[ ] sometimes increased and sometimes decreased.

9. A force is

[ ] a strong object.
[ ] an object which can do work.
[ ] a push or a pull.
[ ] an engine.

10. If you start to slide across a frozen lake which is over a mile wide, you will usually stop before you reach the other side because

[ ] the force of the wind will stop you.
[ ] all moving objects soon stop.
[ ] you always wish to stop.
[ ] a force between the soles of your shoes and the ice stops your motion.

11 The water on the surface of a concrete road often causes an automobile to

[ ] slip to one side.
[ ] drive with greater ease.
[ ] stick to the road better.
[ ] keep in the center of the road.

12. If you wish to move a drum (barrel) of oil across a plank floor you should

[ ] slide the drum on its end.
[ ] slide the drum on its side.
[ ] roll the drum on the edge of its end.
[ ] roll the drum on its side.

13. When one body moves across the surface of another, there is always a force which

[ ] tends to prevent the motion of the body.
[ ] increases the speed with which the body is moving.
[ ] is exactly balanced by some other force
[ ] will keep the body moving forever.

14. The force required to move one body across the surface of another is greatest when

[ ] neither body is scratched.
[ ] one body cuts into the other.
[ ] both bodies are very hard.
[ ] neither body bends under the pressure of the other.

15. Small wheels (casters) are used for the purpose of

[ ] making objects slide more easily.
[ ] making objects slide with greater difficulty.
[ ] supporting objects.
[ ] keeping furniture from wearing holes in carpets or floor coverings.

16. **In winter an automobile requires**
    - [ ] a very heavy oil.
    - [ ] a lighter oil than in summer.
    - [ ] less oil than in summer.
    - [ ] more oil than in summer.

17 **When pulling a box across a surface composed of soft dirt, the force required would be greatest when the box is on its**
    - [ ] edge.
    - [ ] side.
    - [ ] end.
    - [ ] corner.

18. **The force required to drive an automobile over a soft sandy road, compared with the force required to drive an automobile over a smooth hard surface road, is**
    - [ ] less.
    - [ ] more.
    - [ ] the same.
    - [ ] sometimes more and sometimes less.

19. **Automobile chains are used to**
    - [ ] keep the wheels from turning.
    - [ ] make the wheels stronger.
    - [ ] hold the tires to the wheel.
    - [ ] increase the force acting between the tires and the road.

20. **A knife becomes hot when it is held on a grinding stone because**
    - [ ] the stone heats it.
    - [ ] the hands warm it.
    - [ ] work is being changed into heat.
    - [ ] the water on the stone warms it.

21. **More heat is produced in drilling iron than in drilling soft wood because**
    - [ ] the iron holds the heat.
    - [ ] more energy is used in drilling iron.
    - [ ] iron heats more quickly than wood.
    - [ ] the wood carries the heat away rapidly.

22. **We get from a machine**
    - [ ] more work than we put into it.
    - [ ] less work than we put into it.
    - [ ] the same amout of work that we put into it.
    - [ ] sometimes more work than we put into the machine and sometimes less work than we put into it.

23. **Work is done when a**
    - [ ] force moves the body upon which it acts.
    - [ ] force acts on a body.
    - [ ] body moves.
    - [ ] force acts on a body but does not move it.

24. Work is usually measured in

☐ pounds.
☐ feet.
☐ foot pounds.
☐ pounds feet.

25 Which of the following objects can easily be made to yield a large amount of energy?

☐ Decayed wood.
☐ Coal.
☐ Iron.
☐ Salt.

26. Which of the following objects can easily be made to yield a large amount of energy?

☐ A very large stone at the bottom of a well.
☐ Water at the bottom of the ocean.
☐ Ashes on the bottom of the sidewalk.
☐ Gasoline at the bottom of a buried oil tank.

27. After water has struck the bottom of a water fall it has

☐ more energy than it had at the top of the fall.
☐ less energy than it had at the top of the fall.
☐ the same amount of energy it had at the top of the fall.
☐ sometimes more energy and sometimes less energy than it had at the top of the water fall.

28. If you push an automobile across a level garage floor you must push with the greatest force, all factors except the force you exert being uniform,

☐ when starting it.
☐ when stopping it.
☐ when keeping it in uniform motion.
☐ sometimes when starting it and sometimes when stopping it.

29. When pushing a hardened steel block across a very hard surface, the force between the surface and the block would be

☐ greatest on the side.
☐ greatest on the end.
☐ greatest on the edge.
☐ practically the same on all surfaces.

30. Which of the following always represents a type of energy?

☐ Light.
☐ A motor.
☐ A windmill.
☐ A machine.

31. Which of the following always represents a type of energy?
[ ] Sand.
[ ] Wheels.
[ ] An engine.
[ ] Heat.

32. A steam engine is a machine which is used for the purpose of changing
[ ] steam into water.
[ ] live steam into exhaust.
[ ] heat into work.
[ ] work into heat.

33. Energy is always
[ ] ability.
[ ] capacity.
[ ] capacity for doing work.
[ ] what an object has after work has been done on it.

34. When wearing rubbers with smooth soles, it is more difficult to walk on a sidewalk covered with water than it is to walk on a dry sidewalk because
[ ] the soles of rubbers do not stick to water.
[ ] the particles of water slide over each other easily.
[ ] we can not balance ourselves as well.
[ ] we walk faster when it rains.

35. It is not so easy to row a boat on the beach as it is in the water because
[ ] sand sticks to the boat with more force than water.
[ ] the oars can not be used in the sand.
[ ] fluids pull backward with little force on solids moving through them.
[ ] the boat does not sink into the sand.

36. A given mass (weight) of iron possesses the largest amount of energy
[ ] on top of a house.
[ ] inside the house.
[ ] on the ground in front of the house.
[ ] on the cellar floor.

37. If you rub your fingers rapidly on a piece of smooth cloth, it soon becomes very hot and your finger may blister. This heat comes from
[ ] the cloth.
[ ] the finger.
[ ] the air around the finger.
[ ] the energy used to move the finger.

38. A locomotive engineer puts sand on the rails
[ ] to keep them dry.
[ ] to polish their surface.
[ ] to fill the cracks between the rails.
[ ] to increase the pull which the locomotive can exert.

39. A carpet will not slip easily on a hard wood floor when
[ ] wax is placed under the carpet.
[ ] the floor is highly polished.
[ ] a sponge rubber mat is placed under it.
[ ] newspapers are placed under it.

40. Automobiles are streamlined because
[ ] they are more attractive that way.
[ ] they are more comfortable that way.
[ ] the force which opposes their motion through the air is reduced.
[ ] there is less danger of overturning.

41. A force may be measured in
[ ] feet.
[ ] pounds.
[ ] meters.
[ ] gallons.

42. A body moves with the least opposition over the surface of another when
[ ] one surface is smooth and the other surface is rough
[ ] both surfaces are very smooth.
[ ] both surfaces have rough spots and smooth spots.
[ ] both surfaces are very rough.

43. One body generally moves with difficulty across the surface of another body because force must be used
[ ] to lift it out of the hollows into which it sinks.
[ ] to overcome a force which is pulling it backward.
[ ] to aid the opposition.
[ ] to keep any object in motion.

44. Screws hold better than nails because
[ ] they are more highly polished.
[ ] it takes longer to drive them.
[ ] they are usually turned when driven.
[ ] they have ridges on their surfaces.

45. Automobile brake shoes have linings which
[ ] are very smooth.
[ ] are very hard.
[ ] are kept well oiled.
[ ] burn at a very high temperature.

46. The grooved tread on an automobile tire is for the purpose of
[ ] making the tire look better.
[ ] making the tire wear longer.
[ ] making the tire hold small stones in the hollows.
[ ] increasing the force which the tire can exert on the surface of the road.

47. A gasoline engine is used for the purpose of
[ ] burning gasoline.
[ ] changing heat into work.
[ ] changing work into heat.
[ ] heating the radiator.

48. Automobile tires hold better on a soft sandy road when the tires are
[ ] hard.
[ ] soft.
[ ] small.
[ ] smooth.

49. The tires of an automobile are pumped up on a cold morning to full pressure. If the automobile is driven over a hot pavement, the tires may
[ ] shrink.
[ ] become soft.
[ ] rim cut.
[ ] blow out.

50. Why does a bullet become very hot when it strikes a block of iron?
[ ] Because the iron heats it.
[ ] Because the powder in the gun heats it.
[ ] Because the bullet's energy is changed into heat.
[ ] Because it is heated as it passes through the air.

51. Friction is increased when the surfaces are
[ ] wetted.
[ ] dried.
[ ] oiled.
[ ] waxed.

52. Ashes are put on the sidewalk to
[ ] melt the ice.
[ ] increase friction.
[ ] decrease friction.
[ ] make holes in the ice.

53. Water on the surface of a sidewalk
[ ] makes walking easier.
[ ] reduces friction.
[ ] increases friction.
[ ] has no effect on our ability to walk.

54. Friction is
   - [ ] the pull of the earth on an object.
   - [ ] the force that holds two objects together.
   - [ ] the opposition offered to the motion of one body across the surface of another.
   - [ ] any force that opposes motion.

55. When sliding downhill a sled will go most rapidly if there is
   - [ ] a large amount of friction.
   - [ ] no friction.
   - [ ] sometimes a large amount of friction and sometimes very little friction.
   - [ ] very little friction.

56. It is a help when skating to have
   - [ ] a large amount of friction between the bottoms of the skate runners and the ice.
   - [ ] very little friction between the bottoms of the skate runners and the ice.
   - [ ] sand on the ice.
   - [ ] ridges across the bottoms of the runners.

57. Friction is a help when
   - [ ] sliding on a waxed floor.
   - [ ] running a machine.
   - [ ] sawing wood.
   - [ ] sliding an engine across a rough floor.

58. Wax is placed on a dance floor
   - [ ] to give the floor a better appearance.
   - [ ] to increase friction.
   - [ ] to make the soles of shoes wear longer.
   - [ ] to reduce friction.

59. Hard surfaces are roughened by wear
   - [ ] more easily than soft surfaces.
   - [ ] less easily than soft surfaces.
   - [ ] as easily as soft surfaces.
   - [ ] sometimes more easily than soft surfaces and sometimes less easily than soft surfaces.

60. The strands of a rope are held together for the most part by
   - [ ] knots at the end.
   - [ ] friction between the strands.
   - [ ] glue.
   - [ ] twist in the rope.

61. The fibers of cloth are held together for the most part by
   - [ ] filling material between the fibers.
   - [ ] glue.
   - [ ] binding at the edge of the cloth.
   - [ ] friction.

62. If we squeeze tightly when a rope is drawn through our hands, friction
☐ is decreased.
☐ is increased.
☐ remains the same.
☐ is sometimes decreased and sometimes increased.

63. Friction is a help when
☐ we cut a cake.
☐ sliding an object along the ground.
☐ an arrow moves through the air.
☐ turning a door knob.

64. Friction is a help when one is
☐ standing still.
☐ sitting in a chair.
☐ resting on a bed.
☐ starting to run a race.

65. Friction works against us when we
☐ run a race.
☐ stop an automobile.
☐ move an object.
☐ pull on a rope.

66. Nails are held in place by
☐ the great force required to drive them.
☐ a natural glue found between the fibers of the wood.
☐ friction.
☐ gravity.

67 Friction is a disadvantage in the use of wood screws because
☐ it makes them drive harder.
☐ it makes them hold better.
☐ it makes them easier to remove.
☐ they are shorter than nails.

68. Before driving a screw, a carpenter puts soap on it to
☐ clean the surface.
☐ make the screw stick to the wood.
☐ reduce friction.
☐ increase friction.

69. A wedge is held in place by
☐ the opposition of the material into which it is driven.
☐ pressure on its sides.
☐ the friction along its sides.
☐ a force pulling it into the material.

70. Machine belts are kept from slipping in most cases
[ ] by friction.
[ ] by being stretched very tightly.
[ ] because they are made of heavy material.
[ ] because they are so narrow.

71. Screws hold firmly because they
[ ] have friction
[ ] have a grooved head.
[ ] taper.
[ ] are smooth.

72. Friction hinders us when we
[ ] slide a heavy object across the floor.
[ ] push on the floor with our feet to move an object.
[ ] pull on a rope.
[ ] lift an object.

73. Friction is a help
[ ] in the bearings of roller skates.
[ ] when you wish to slide down an inclined board.
[ ] when turning a key in a lock.
[ ] when filing a notch in a piece of iron.

74. The friction on the surface of a carpet, when compared with that on the surface of a smooth hardwood floor is
[ ] greater.
[ ] less.
[ ] the same.
[ ] sometimes greater and sometimes less.

75. Bottom friction is an advantage when
[ ] skiing uphill.
[ ] skiing downhill.
[ ] skiing on the level.
[ ] on the ski tow.

76. Jewels are used in watches to
[ ] make them look better.
[ ] make them cost more.
[ ] reduce friction.
[ ] keep the shafts from wearing.

77. When changing from sliding friction to rolling friction, the amount of friction
[ ] increases.
[ ] decreases.
[ ] remains the same.
[ ] sometimes increases and sometimes decreases.

78. Wheels are used to
[ ] change rolling friction to sliding friction.
[ ] change sliding friction to rolling friction.
[ ] make objects move more smoothly.
[ ] make objects more stable.

79. Wheels are used to
[ ] raise objects above the ground.
[ ] improve the appearence of objects.
[ ] reduce friction.
[ ] increase friction.

80. When changing from rolling friction to sliding friction the amount of friction
[ ] increases.
[ ] decreases.
[ ] remains the same.
[ ] sometimes increases and sometimes decreases.

81. Oil keeps an automobile engine cool because it
[ ] reduces friction.
[ ] absorbs a very large amount of energy.
[ ] carries a large quantity of heat away from the engine.
[ ] destroys heat when it is consumed.

82. When oil becomes cold it flows more slowly because the internal friction
[[disappears
[ ] remains the same.
[ ] becomes less.
[ ] becomes greater.

83. The effect of extent of surface on friction is usually
[ ] very great.
[ ] moderate.
[ ] none under normal conditions
[ ] to increase friction when the extent of surface is increased.

84. Water near the bank of a river moves more slowly than water near the middle of the river because
[ ] it is nearer the bank.
[ ] it is nearer the bottom.
[ ] of internal friction.
[ ] water near the middle of the stream is denser.

85. Friction is an advantage when grinding a knife because
[ ] the knife becomes sharp more quickly.
[ ] it requires more force to turn the grinding stone.
[ ] heat may draw the temper from the knife.
[ ] it is difficult to hold the knife on the stone.

86. Friction is a disadvantage when grinding because

[ ] the stone soon gives the knife a thin edge.
[ ] heat may draw the temper from the knife.
[ ] the knife wears away more quickly.
[ ] it makes the knife have a keen edge.

87. Friction is a disadvantage when drilling because

[ ] the material is drilled more quickly.
[ ] less effort is required.
[ ] the drill gets hot more quickly.
[ ] the drill stays sharp longer.

88. Nuts remain on bolts better if the threads of the bolts are

[ ] oiled.
[ ] dry and rough.
[ ] greased.
[ ] cut with very smooth surfaces.

89. Friction is not an advantage

[ ] between an automobile tire and the road.
[ ] when starting to run a race.
[ ] between the clutch surfaces of an automobile.
[ ] between the axle of an automobile and the bearing in the wheel.

90. Friction is reduced when

[ ] the ridges of one substance fit into the hollows of another substance when sliding across it.
[ ] the ridges of one substance are lifted out of the hollows of another without sliding motion.
[ ] the ridges and hollows are made larger.
[ ] the surfaces are made very rough.

91. Friction can be increased by

[ ] making the load lighter.
[ ] increasing the force pressing the surfaces together.
[ ] increasing the smoothness of the surfaces.
[ ] increasing the hardness of the surfaces.

92. Friction is made greater when

[ ] two hard surfaces are used.
[ ] two soft surfaces are used.
[ ] one hard surface and one soft surface are used.
[ ] a sheet of rubber is placed between two hard rough surfaces.

93. A force is measured in

[ ] kilometers.
[ ] quarts.
[ ] ounces.
[ ] yards.

94. You are "working" if you
- ☐ overcome a force which resists motion.
- ☐ slide an object with uniform velocity along a level surface which is without friction.
- ☐ hold a hundred pound weight stationary in your hand for ten minutes.
- ☐ drop a fifty pound weight.

95. Work is always done when
- ☐ a force is exerted.
- ☐ you push on an object.
- ☐ you pull on an object.
- ☐ resistance is overcome.

96. Energy used to overcome friction usually
- ☐ comes from the machine in the form of useful work.
- ☐ is absorbed and retained by the machine itsself.
- ☐ passes off as heat.
- ☐ is stored up for future use.

97. If the wheels of a locomotive start to slip, they spin rapidly because
- ☐ the engineer turns on more steam.
- ☐ friction when starting is greater than it is after motion is secured.
- ☐ the wheels become smoother.
- ☐ the engineer oils the track.

98. On dry surfaces rubber usually offers
- ☐ more friction than leather.
- ☐ less friction than leather.
- ☐ more friction than sand paper.
- ☐ less friction than metals.

99. Friction is a force which
- ☐ holds chairs against the floor.
- ☐ makes bureau drawers stick.
- ☐ causes a person to slide on a smooth surface.
- ☐ causes belts to slip.

100. The force which vibrates a violin string is usually due to
- ☐ friction.
- ☐ a blow struck by the bow.
- ☐ strain in the strings.
- ☐ frictionless rubbing of the strings by the bow.

TEST ON FRICTION

Prepared by

RALPH B. DELANO

Memorial High School, Boston, Massachusetts

Form B

Your name .... Boy ...... Girl

Name of school .... City ....

Your age at last birthday .... When were you born ....
Month Day Year

Date .... Teacher's name ....

Write below the name of the science (nature study, general science, biology, science I, science II, physics, chemistry, etc.) you studied in each grade. If you did not study a science in any of the grades listed below, write "No Science" after that particular grade.

Grade V .... Grade IX ....

Grade VI .... Grade X

Grade VII .... Grade XI ....

Grade VIII .... Grade XII ....

In what particular application of science are you most interested? Check one of the following scientific devices or add the name of some practical machine which appeals to you.

1. Radio
2. Automobile
3. Airplane
4. Camera
5. Engines
6. ....

22

DIRECTIONS FOR MARKING THE TEST

Put an X, in the brackets, before the most nearly correct completion word, statement, or answer. Use only one X for each numbered question. Do not write anything or mark the test in any other way.

1. Example Number 1

1. A circle is

[ ] square.
[X] round.
[ ] rectangular.
[ ] longer than it is wide.

Example Number 2

2. If a sidewalk is covered with one of the following substances, on which material would you be most likely to slip?

[ ] Sand.
[ ] Ashes.
[ ] Dirt.
[X] Ice.

Go through the booklet and answer first the questions which you can answer most easily. Then go back and try to answer as many of the other questions as you can. Keep working until you are told to stop. WORK RAPIDLY.

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TEST ON FRICTION

101. When oil or grease is used, friction is

[ ] decreased.
[ ] increased.
[ ] unchanged.
[ ] decreased by oil and increased by grease.

102. The resistance offered to the continued motion of one body across the surface of another is usually due to

[ ] a third substance between the bodies.
[ ] the tendency of all bodies to remain at rest.
[ ] the fact that we become tired after pulling an object a long distance.
[ ] the fact that projections on the surfaces of the bodies must be broken off or worn down during the motion.

103. A match can be lighted best on a surface which has

[ ] a large amount of friction.
[ ] a moderate amount of friction.
[ ] no friction at all.
[ ] rough spots alternating with smooth spots.

104. Heat causes most substances to

[ ] contract.
[ ] expand.
[ ] remain the same.
[ ] become shorter in some cases and longer in others.

105. When holding a book in a vertical position between the thumb and forefinger, the projections on the surface of the skin and on the surface of the book

[ ] aid us in holding the book.
[ ] make it difficult to hold the book.
[ ] have no effect on the force required to hold the book.
[ ] sometimes aid and sometimes hinder our efforts to hold the book.

106. Projections on the soles of our shoes and on the surfaces on which we walk are a help to us when we

[ ] dance.
[ ] run a race.
[ ] slide across the surface of the ice on a small pond.
[ ] ask someone to pull us across a polished floor.

107. Rough surfaces are not a help

[ ] when standing on a sloping roof.
[ ] in machine bearings.
[ ] when we wish to stop suddenly.
[ ] When lifting a post.

108. **The fibers of a string are held together for the most part by**
[ ] the projections on their surfaces.
[ ] material placed between the fibers.
[ ] glue.
[ ] knots.

109. **It is a help when sliding to**
[ ] cut notches in the sled runners.
[ ] have the runners at the same temperature as the snow.
[ ] have the sled runners colder than the snow.
[ ] have the sled runners warmer than the snow.

110. **Friction is usually a help**
[ ] in the bearings of a machine.
[ ] when walking.
[ ] in the cylinder of an automobile.
[ ] between the runners of a sled and the ground.

111. **Friction becomes less when**
[ ] both surfaces are uneven.
[ ] one surface contains hollows and the other surface has projections.
[ ] both surfaces are very smooth.
[ ] one surface is smooth and the other surface has ridges.

112. **Friction is increased**
[ ] by filling the hollows in a surface.
[ ] by making the surfaces rough.
[ ] by removing all surface projections.
[ ] by putting a heavy liquid between two surfaces.

113. **When smokes come from under a trolley car, it is a sign that**
[ ] a fire, used to heat the car, is burning underneath.
[ ] some substance is burning because heat is being generated by the rubbing of one metal surface against another.
[ ] the material on the electric wires is burning.
[ ] men are smoking in the car.

114. **Friction may usually be reduced by**
[ ] changing sliding friction to rolling friction.
[ ] making surfaces more irregular.
[ ] using as bearing metal the same material that makes up the composition of the shaft.
[ ] using surfaces which are soft and flexible.

115. **If you could buy roller skates with ball bearings and without ball bearings for the same price, you would buy the skates with ball bearings because**
[ ] they look better.
[ ] more labor was used in making them.
[ ] they are heavier.
[ ] they have less friction.

116. Roller bearings are used to
- [ ] make machines wear longer.
- [ ] increase the cost of machines.
- [ ] make machines have more friction.
- [ ] make machines use more oil.

117. Which of the following objects has energy which is easily obtained ?
- [ ] A block of marble at the bottom of a quarry.
- [ ] Gunpowder.
- [ ] Water at the bottom of a water fall.
- [ ] A stone in the ground.

118. The force required to slide one body over another will be greatest when
- [ ] both bodies have very smooth surfaces.
- [ ] one body is smooth and the other body is rough.
- [ ] one body has many small projections which to fit in many small hollows in the other body.
- [ ] one body has many large projections which fit into many large hollows in the other body.

119. When the force pressing two objects together is increased friction is
- [ ] increased.
- [ ] decreased.
- [ ] unchanged.
- [ ] sometimes increased and sometimes decreased.

120. When the force pressing two objects together is doubled, friction is
- [ ] decreased
- [ ] unchanged.
- [ ] doubled.
- [ ] four times as great.

121. In all machines
- [ ] input + energy of friction = output.
- [ ] output + energy of friction = input.
- [ ] output × energy of friction = input.
- [ ] output — energy of friction = input.

122. If a book is placed on a table, the table is exerting
- [ ] an upward force on the book.
- [ ] a downward force on the book.
- [ ] no force on the book.
- [ ] a force tending to move the book to one side.

123. When you are sitting in a chair,
- [ ] there are no forces acting on you.
- [ ] there are always at least two large forces acting on you.
- [ ] there is a time when only a single force acts on you.
- [ ] you are always conscious of exerting a force.

124. **The friction of a steel shaft in a brass bearing is**
[ ] the same as in a steel bearing.
[ ] greater than in a steel bearing.
[ ] less than in a steel bearing.
[ ] greater than in an iron bearing.

125. **Friction is reduced when**
[ ] the hollows and ridges of one substance fit the ridges and hollows of another substance.
[ ] the hollows and ridges of one substance do not fit the ridges and hollows of another substance.
[ ] the same kinds of metals are used for bearing surfaces
[ ] the ridges and hollows are equally spaced on the two substances.

126. **Oil and grease are used most effectively when**
[ ] only the hollows are filled.
[ ] only the ridges of the surfaces are in contact.
[ ] the film of oil or grease prevents contact between the surfaces.
[ ] there is practically no friction.

127. **Roller bearings**
[ ] increase the operating temperature of machines.
[ ] decrease the operating temperature of machines.
[ ] have no effect on the operating temperature of machines
[ ] sometimes increase and sometimes decrease the operating temperature of machines.

128. **Ball bearings are used to**
[ ] increase the cost of machines.
[ ] increase the effort used to operate machines.
[ ] reduce the cost of machines.
[ ] reduce the effort used to operate machines.

129. **Ball bearings**
[ ] increase the running expense of a machine.
[ ] decrease the running expense of a machine.
[ ] have no effect on the running expense of a machine.
[ ] sometimes increase and sometimes decrease the running expense of a machine.

130. **Roller bearings are used to**
[ ] make machines run without noise.
[ ] reduce friction.
[ ] improve the appearance of machines.
[ ] increase friction

131. **A very light oil is used when the**
[ ] bearings are large and under great pressure.
[ ] bearings are small and under little pressure.
[ ] temperature is high.
[ ] temperature is moderate.

132. **A heavy oil is used**
   - ☐ when the temperature is high
   - ☐ when the temperature is low.
   - ☐ when the temperature is moderate.
   - ☐ without regard for temperature.

133. **Bearings having heavy pressure require**
   - ☐ light oil.
   - ☐ no oil.
   - ☐ very little oil.
   - ☐ cup grease.

134. **A watch bearing requires**
   - ☐ heavy machine oil.
   - ☐ cup grease.
   - ☐ graphite.
   - ☐ a light sperm oil.

135. **Friction**
   - ☐ increases the efficiency of a machine.
   - ☐ decreases the efficiency of a machine.
   - ☐ has no effect on the efficiency of a machine.
   - ☐ sometimes increases and sometimes decreases the efficiency of a machine.

136. **Friction between solids**
   - ☐ remains unchanged when the speed changes.
   - ☐ sometimes increases and sometimes decreases with increasing speed.
   - ☐ increases with increasing speed.
   - ☐ decreases with increasing speed.

137. **The efficiency of a machine which has no friction would be**
   - ☐ 10 per cent.
   - ☐ 50 per cent.
   - ☐ 100 per cent.
   - ☐ 200 per cent.

138. **If you can just exert force enough to start a heavy object, you should**
   - ☐ try to keep the object in rapid motion across the most difficult places.
   - ☐ try to stop the object in places where the friction is greatest.
   - ☐ try to move the object very slowly in places where the friction is greatest.
   - ☐ try to pay no attention to the fact that the surface over which motion is taking place is not uniform.

139. **Work is done when**
   - ☐ there is resistance to motion.
   - ☐ we exert ourselves.
   - ☐ opposition is overcome.
   - ☐ objects are moved with constant speed without fiction.

140. Which of the following has energy of motion?
- [ ] A coiled spring.
- [ ] Coal.
- [ ] A bullet being fired from a rifle.
- [ ] Gunpowder.

141. A thermometer indicates
- [ ] how hot things are.
- [ ] the heat capacity of a substance.
- [ ] the quantity of heat a substance contains.
- [ ] the amount of friction a body possesses.

142. Between the freezing point and the boiling point on the Fahrenheit scale there are
- [ ] 100 degrees.
- [ ] 160 degrees.
- [ ] 180 degrees.
- [ ] 200 degrees.

143. Water boils at
- [ ] 100 degrees Fahrenheit.
- [ ] 110 degrees Fahrenheit.
- [ ] 200 degrees Fahrenheit
- [ ] 212 degrees Fahrenheit.

144. Water freezes at
- [ ] 0 degrees Fahrenheit.
- [ ] 10 degrees Fahrenheit.
- [ ] 12 degrees Fahrenheit.
- [ ] 32 degrees Fahrenheit.

145. A calorie is a unit used
- [ ] when comparing the temperature of two bodies.
- [ ] when comparing the quantity of heat possessed by two bodies.
- [ ] in measuring the temperature of a body.
- [ ] in measuring the degree of heat which a body possesses.

146. A calorie is a unit used to measure the
- [ ] quantity of heat.
- [ ] degrees of heat.
- [ ] quality of heat.
- [ ] range of heat.

147. The weight of a man at either pole of the earth compared to his weight at the equator would be
- [ ] the same
- [ ] less.
- [ ] more.
- [ ] $\frac{1}{2}$ as much

148. **When a driver tries to start an automobile on an icy street, the rear wheels often spin. This is due to**
[ ] lack of friction.
[ ] too much friction.
[ ] too much horse power in the engine.
[ ] an inexperienced driver.

149. **The name of the force which always resists the motion of one body across the surface of another is**
[ ] gravity.
[ ] friction.
[ ] weight.
[ ] effort

150. **An automobile engine has a higher efficiency than**
[ ] a locomotive.
[ ] an electric motor.
[ ] a bicycle.
[ ] a sewing machine.

151. **Friction may be increased by**
[ ] the use of oil or grease.
[ ] the use of roller or ball bearings.
[ ] putting sand between the surfaces.
[ ] putting graphite between the surfaces.

152. **Large bearings, which can not be greased often, require**
[ ] a very light oil.
[ ] a light cup grease.
[ ] a graphite grease.
[ ] no grease at all

153. **Friction is a disadvantage in an automobile steering worm if it**
[ ] increases the force required to steer the car.
[ ] keeps the worm smooth.
[ ] keeps jolts from the hands.
[ ] helps to keep the front system from vibrating.

154. **Friction is an advantage in the steering worm of an automobile because it**
[ ] makes steering take place less rapidly.
[ ] gives the steering wheel less ease of motion.
[ ] decreases the mechanical advantage.
[ ] keeps wheel jolts from reaching the hands of the driver.

155. **Skates are sharpened for the purpose of**
[ ] making the bottoms of the runners smooth.
[ ] decreasing friction along the edges of the runners.
[ ] making the edges of the runners cut into the ice.
[ ] making the edges of the runners smooth.

156. Rosin is placed on a violin bow to

[ ] decrease friction.
[ ] make the bow stronger.
[ ] keep the bow from wearing out.
[ ] increase friction.

157. The force which usually stops an automobile is

[ ] friction between the brake bands and the brake drum.
[ ] the force applied to the brakes.
[ ] the force exerted by the engine.
[ ] the friction between the tires and the surface of the road.

158. The force which starts an automobile is usually limited by the

[ ] power of the engine.
[ ] strength of the gears.
[ ] friction between the tires and the road.
[ ] friction between the pistons and the cylinders.

159. An automobile is stopped by

[ ] pushing on the brake pedal.
[ ] friction.
[ ] the engine.
[ ] the brakes.

160. The driving power of an automobile is carried from one clutch surface to the other by

[ ] a spring.
[ ] grease.
[ ] friction.
[ ] a shaft.

161. A gasoline engine has a low efficiency because of

[ ] friction.
[ ] incomplete combustion.
[ ] the large quanitity of oil used.
[ ] loss of heat in exhaust gases and cooling system.

162. If your automobile is stalled in loose sand, you should

[ ] let the clutch in suddenly when the engine is running rapidly.
[ ] rotate the rear wheels at high speed.
[ ] rotate the rear wheels as slowly as possible.
[ ] pay no attention to the speed of rotation of the rear wheels.

163. In all machines

[ ] $\text{output} = \text{input} \div \text{efficiency}$.
[ ] $\text{efficiency} = \text{input} \times \text{output}$.
[ ] $\text{input} = \text{efficiency} + \text{output}$.
[ ] $\text{output} = \text{efficiency} \times \text{input}$.

164. **Efficiency is equal to the**
[ ] ratio of the total work done on a machine to the useful work done by the machine.
[ ] useful output divided by the work lost in the machine.
[ ] difference detween the input and the friction.
[ ] work got out divided by the work put in.

165. **We measure forces with**
[ ] an equal arm balance.
[ ] a spring balance.
[ ] a meter stick.
[ ] friction.

166. **If 300 foot pounds of work are put into a machine in order to get 240 foot pounds of work from it, the efficiency is**
[ ] 40 per cent.
[ ] 60 per cent.
[ ] 80 per cent.
[ ] 125 per cent.

167. **A wheel can not be made to have perpetual motion because of**
[ ] lack of sufficient power.
[ ] our limited knowledge of machine construction.
[ ] the fact that all substances soon wear out.
[ ] friction.

168. **You are doing "work" when you**
[ ] support for an hour one end of a log weighing 100 pounds without moving the log.
[ ] lift a postage stamp from the floor to the table.
[ ] push against a stationary wall with all your strength for one hour.
[ ] try to pull a fence post from the ground but find you do not move it.

169. **Friction is a disadvantage in jackscrews because it**
[ ] keeps them from slipping.
[ ] keeps the screw smooth.
[ ] makes them operate more easily.
[ ] increases the force required to operate them.

170. **The efficiency of the jackscrew is**
[ ] 25 per cent.
[ ] 80 per cent.
[ ] 90 per cent.
[ ] 100 per cent.

171. A ball will roll the greatest distance after leaving your hand if you roll it on
[ ] a rough floor.
[ ] a carpet.
[ ] dirt.
[ ] smooth, dry ice.

172. Fluid friction is generally
[ ] equal to sliding friction between solids.
[ ] equal to rolling friction between solids.
[ ] less than sliding friction between solids.
[ ] greater than sliding friction between solids.

173. The usual number showing the relation between the force needed to overcome sliding friction on a horizontal surface and the weight of the object moved is obtained by
[ ] multiplying the weight by the force.
[ ] subtracting the force from the weight.
[ ] dividing the weight by the force.
[ ] dividing the force by the weight.

174. The relation between the force needed to overcome rolling friction and the force pressing the objects together is obtained by
[ ] subtracting one force from the other.
[ ] multiplying the two forces together.
[ ] dividing the friction by the pressing force.
[ ] dividing the pressing force by the friction.

175. The number showing the ratio between friction and the weight of a ten pound block of iron pulled over a hardwood floor is the same as that between friction and the weight of a
[ ] 10 pound block of lead pulled over the same floor.
[ ] 500 pound block of iron pulled over the same floor.
[ ] 500 pound block of brass pulled over the same floor.
[ ] 10 pound block of iron pulled over a pine floor.

176. The number showing the ratio between friction on a horizontal surface and the weight of the object being moved
[ ] is almost always constant for the same surfaces.
[ ] varies with the load.
[ ] almost always varies for the same surfaces.
[ ] has the same values for different kinds of surfaces.

177. The fact that more force is required to pull a box filled with bricks across a floor than is required to pull the empty box results from the fact that the ratio between friction and weight
[ ] increases with the weight.
[ ] decreases with the weight.
[ ] is independent of the weight.
[ ] is dependent on the weight.

178. A good lubricant should

[ ] contain gritty substances.
[ ] corrode the bearings.
[ ] evaporate readily.
[ ] not be squeezed out of the bearings by pressure.

179. The mechanical equivalent of heat is a figure showing the quantity of

[ ] work which can be obtained from one heat unit.
[ ] heat which can be secured from one unit of work.
[ ] heat which can be secured from a mehanical device.
[ ] work which can be secured from friction.

180 If the runners of your sled were twice as wide, the force required to draw the sled across smooth, dry ice would be

[ ] $\frac{1}{2}$ as much.
[ ] nearly the same.
[ ] twice as much.
[ ] four times as much.

181. Friction, when starting an object

[ ] is less than it is after motion is secured.
[ ] is greater than it is after motion is secured.
[ ] is the same as it is after motion is secured.
[ ] has no constant relation to the amount of friction after motion is secured.

182. The thermometer most commonly used in this country is the

[ ] air thermometer.
[ ] centigrade thermometer.
[ ] Fahrenheit thermometer.
[ ] clinical thermometer.

183. If you hook four spring balances together and pull until each indicates 10 pounds, you will be pulling with a force equal to

[ ] 10 pounds.
[ ] 20 pounds.
[ ] 30 pounds.
[ ] 40 pounds.

184. Degrees of temperature are

[ ] whole numbers which show how hot things are.
[ ] fractions which show the amount of heat in a body.
[ ] whole numbers which show how cold things are.
[ ] fractions which show the difference between the freezing point and the boiling point of water.

185. A steam turbine is always operated to

[ ] obtain electricity.
[ ] propel ships.
[ ] change heat into work.
[ ] change work into heat.

186. When surfaces are well oiled, friction
[ ] increases when the area is increased.
[ ] decreases when the area is increased.
[ ] remains the same when the area is increased
[ ] has no relation to the area.

187. Which would do the most damage when striking the front of a building?
[ ] A 2000 pound car going 88 feet per second.
[ ] A 2670 pound car going 66 feet per second.
[ ] A 3000 pound car going 58 feet per second.
[ ] A 4280 pound car going 40 feet per second.

188. Friction is caused by
[ ] irregularities in the surfaces.
[ ] weight.
[ ] inertia.
[ ] adhesion.

189. When we exert greater pressure on the brake pedal of an automobile, the friction of the breaking surfaces
[ ] is increased.
[ ] is decreased.
[ ] remains the same.
[ ] sometimes increases and sometimes decreases.

190. Friction is an advantage in a jackscrew because it
[ ] causes more force to be used in its operation.
[ ] causes the screw to work less rapidly.
[ ] keeps the screw from slipping.
[ ] decreases the efficiency of the machine.

191. For skiing down hill, skis should be
[ ] smooth on the bottom.
[ ] rough on the bottom.
[ ] made with notches running across them.
[ ] made with a large amount of friction.

192. For skiing uphill skis should be
[ ] rough on the bottom.
[ ] polished on the bottom.
[ ] covered with a hard, smooth wax.
[ ] made with a small amount of friction.

193. The brake shoes of an automobile are lined with a substance which has a
[ ] very smooth surface.
[ ] very hard surface.
[ ] high coefficient of friction.
[ ] low coefficient of friction.

194. Friction is increased by

[ ] increasing the pressure.
[ ] reducing the acceleration due to gravity.
[ ] reducing the mass.
[ ] increasing the velocity.

195. Rolling friction is increased when

[ ] large wheels are used.
[ ] small wheels are used.
[ ] ball bearings are used.
[ ] smooth tires are used.

196. A good illustration of the use of different materials to reduce friction is

[ ] a Babbitt box in the hub of a wheel.
[ ] wood in the pendulum of a clock.
[ ] iron in the brass balance wheel of a watch.
[ ] aluminum pistons in the iron cylinder of an automobile.

197. Tractors have cleats on their wheels to

[ ] make the wheels stronger.
[ ] keep dirt from sticking to the wheels.
[ ] increase friction.
[ ] decrease friction.

198 If we do not lock the wheels when stopping an automobile, the car will not skid unless the friction is very small because

[ ] the weight of the car will carry it forward.
[ ] the turning wheels always make the car go forward.
[ ] rolling friction is less than sliding friction.
[ ] the engine always makes the car go forward.

199. Water on the surface of a tar road usually results in

[ ] the skidding of a motor vehicle.
[ ] an increase in the coefficient of friction.
[ ] a decrease in the uniformity of the surface.
[ ] an increase in the component of gravity producing sidewise motion.

200. Friction, when skating, is

[ ] increased when the temperature of the ice is at the fusion point.
[ ] increased when there is a very thin film of water on the ice.
[ ] decreased when the surface of the ice has irregularities.
[ ] decreased when the ice melts due to the increased pressure under the skate.

TEST ON FRICTION

Prepared by

RALPH B. DELANO

Memorial High School, Boston, Massachusetts

Form C

Your name .... Boy .... Girl ....

Name of school .... City ....

Your age at last birthday .... When were you born ....
Month Day Year

Date .... Teacher's name ....

Write below the name of the science (nature study, general science, biology, science I, science II, physics, chemistry, etc.) you studied in each grade. If you did not study a science in any of the grades listed below, write "No Science" after that particular grade.

Grade V ....

Grade VI ....

Grade VII ....

Grade VIII ....

Grade IX ....

Grade X ....

Grade XI ....

Grade XII ....

In what particular application of science are you most interested? Check one of the following scientific devices or add the name of some practical machine which appeals to you.

1. Radio
2. Automobile
3. Airplane
4. Camera
5. Engines
6.

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DIRECTIONS FOR MARKING THE TEST

Put an X, in the brackets, before the most nearly correct completion word, statement, or answer. Use only one X for each numbered question. Do not write anything or mark the test in any other way.

Example Number 1.

1. A circle is

[ ] square.
[X] round.
[ ] rectangular.
[ ] longer than it is wide.

Example Number 2

2. If a sidewalk is covered with one of the following substances, on which material would you be most likely to slip?

[ ] Sand.
[ ] Ashes.
[ ] Dirt.
[X] Ice.

Go through the booklet and answer first the questions which you can answer most easily. Then go back and try to answer as many of the other questions as you can. Keep working until you are told to stop. WORK RAPIDLY.

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TEST ON FRICTION

201. If it requires a push of three tons to force a ship through the water at a high rate of speed, the force required to push the ship through the water at three times as much speed will be nearly equal to
[ ] 30 tons.
[ ] 18 tons.
[ ] 9 tons.
[ ] 6 tons.

202. An oil of high viscosity has
[ ] little body.
[ ] low density.
[ ] high molecular friction.
[ ] great value when used at a very low temperature.

203. The motorman on an electric car reduces the force acting on his brakes as his speed becomes less because
[ ] the force tending to stop the car becomes greater at low speed.
[ ] the force tending to stop the car becomes less at low speed.
[ ] he does not wish to wear out the brakes.
[ ] the car needs more braking force as it slows down.

204. The force of friction is
[ ] independent of the weight.
[ ] a factor which changes with the weight but which is not proportional to the weight.
[ ] inversely proportional to the weight or total pressing force.
[ ] directly proportional to the weight or pressing force.

205. Friction between hard surfaces is
[ ] inversely proportional to the extent of surface.
[ ] directly proportional to the extent of surface.
[ ] unchanged by the extent of surface.
[ ] irregularly affected by the extent of surface.

206. Energy of position is called
[ ] potential.
[ ] kinetic.
[ ] adiabatic.
[ ] centrifugal.

207. One type of energy is known as
[ ] frictionless energy.
[ ] magnetic energy.
[ ] electrolytic energy.
[ ] kinetic energy.

208. One type of energy is known as
[ ] isochronous energy.
[ ] centrifugal energy.
[ ] potential energy.
[ ] frictional energy.

209. Energy of motion is called
[ ] potential energy.
[ ] kinetic energy.
[ ] adiabatic energy.
[ ] centrifugal energy.

210. Energy is measured in
[ ] volts.
[ ] farads.
[ ] joules.
[ ] maxwells.

211. Energy is measured in
[ ] foot pounds.
[ ] liters.
[ ] degrees.
[ ] degrees of friction.

212. A minor force that may have something to do with friction is
[ ] centrifugal force.
[ ] centripetal force.
[ ] force of expansion.
[ ] force of adhesion.

213. Energy is measured in
[ ] watts.
[ ] pounds.
[ ] dynes.
[ ] ergs.

214. Molecules are
[ ] any small particles.
[ ] the smallest divisions of matter which can be made without destroying their characteristic chemical properties.
[ ] the smallest particles into which matter can be subdivided.
[ ] substances which retain their identity when divided.

215. Molecules are
[ ] larger than atoms.
[ ] smaller than atoms.
[ ] the same size as atoms.
[ ] independent of atoms in regard to size.

216. The molecules of gases
[ ] always touch each other.
[ ] are generally separated by distances which are less than the diameter of the molecule.
[ ] support automobiles by the blows they strike on the surface of the inner tubes.
[ ] are usually stationary.

217. The space between molecules is usually
[ ] largest in solids.
[ ] smallest in liquids.
[ ] largest in liquids.
[ ] largest in gases.

218. Most molecules
[ ] can be seen with the naked eye.
[ ] can be seen with a microscope.
[ ] measure less than 0.000001 inch in diameter.
[ ] can be seen with an ordinary magnifying glass.

219. A drop of water can be divided
[ ] indefinitely.
[ ] into atoms of water.
[ ] into protons of water.
[ ] into molecules of water.

220. If a stone weighing 100 grams moves with a velocity of 10 meters per second, its energy is equal to
[ ] 50,000,000 ergs.
[ ] 1,000 gram meters.
[ ] 500 grams meters.
[ ] 100,000 dynes.

221. Heat is
[ ] an invisible substance.
[ ] a weightless fluid.
[ ] molecular energy.
[ ] a gas obtained from hot substances.

222. A hot substance differs from a cold substance because
[ ] its molecules are moving faster.
[ ] its molecules are moving more slowly.
[ ] a third substance, known as heat, is found between its molecules.
[ ] it has increased weight.

223. In comparison with a cold substance, the molecules of a hot substance
[ ] are much larger.
[ ] are moving more slowly.
[ ] have more energy.
[ ] are usually closer together.

224. When the molecular motion of a substance decreases, the temperature
[ ] decreases.
[ ] increases.
[ ] remains the same.
[ ] sometimes increases and sometimes decreases

225. Water usually boils on the centigrade scale at
[ ] 100 degrees.
[ ] 110 degrees.
[ ] 200 degrees.
[ ] 212 degrees.

226. Water usually freezes on the centigrade scale at
[ ] 0 degrees.
[ ] 10 degrees.
[ ] 32 degrees.
[ ] 100 degrees.

227. There are between the freezing point and the boiling point on the centigrade scale
[ ] 100 degrees.
[ ] 160 degrees.
[ ] 180 degrees.
[ ] 200 degrees.

228. A centigrade degree indicates a temperature change
[ ] greater than a Fahrenheit degree.
[ ] smaller than a Fahrenheit degree.
[ ] the same as a Fahrenheit degree.
[ ] $\frac{5}{9}$ as large as a Fahrenheit degree.

229. A British Thermal Unit is a unit used
[ ] to measure degrees of heat.
[ ] to measure quantity of heat.
[ ] to measure quality of heat.
[ ] when comparing the temperature of two bodies.

230. A British thermal unit is
[ ] a unit used in measuring the temperature of a body.
[ ] the amount of heat contained in one pound of water.
[ ] the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit.
[ ] the amount of heat required to raise the temperature of one quart of water one degree Fahrenheit.

231. A British thermal unit is the amount of heat required to raise the temperature of
[ ] one pound of water one degree centigrade.
[ ] one gram of water one degree Fahrenheit.
[ ] $\frac{1}{2}$ pound of water 2 degrees Fahrenheit.
[ ] 2 pounds of water 1 degree Fahrenheit.

232. **A calorie is the amount of heat required to raise the temperature of one**

[ ] quart of water one degree centigrade.
[ ] gram of water one degree Fahrenheit.
[ ] gram of water one degree centigrade.
[ ] pound of water one degree centigrade.

233. **The number of calories required to raise the temperature of 5 grams of iron 70 degrees centigrade is about**

[ ] 350.
[ ] 75.
[ ] 35.
[ ] 12.

234. **The number of British Thermal Units required to raise the temperature of 20 pounds of iron 50 degrees Fahrenheit is**

[ ] 1,000.
[ ] 100.
[ ] 70.
[ ] 30.

235. **The number of British Thermal Units required to raise the temperature of 10 pounds of water 30 degrees Fahrenheit is**

[ ] 20.
[ ] 40.
[ ] 300.
[ ] 310.

236. **The coefficient of sliding friction on a horizontal surface is the ratio of the**

[ ] force needed to overcome friction to the weight of the object moved.
[ ] weight of the moving object to the weight of the stationary object.
[ ] force needed to overcome friction to the weight of the stationary object.
[ ] weight of the object moved to the force needed to overcome friction.

237. **The coefficient of sliding friction equals**

[ ] friction ÷ pressing force.
[ ] pressing force ÷ friction.
[ ] friction × pressing force.
[ ] pressing force + friction.

238. **The coefficient of rolling friction equals the ratio of the**

[ ] pressure causing friction to the friction.
[ ] weight of the object to the acceleration due to gravity.
[ ] mass of the object being moved to the weight of the stationary object.
[ ] force of friction to the pressing force

239. **The coefficient of rolling friction equals**
[ ] pressing force ÷ friction.
[ ] friction × pressing force.
[ ] friction ÷ pressing force.
[ ] pressing force — friction.

240. **If you can exert a push of 100 pounds and the coefficient of rolling friction is 0.02, you can roll along a horizontal surface, an object weighing**
[ ] 1,000 pounds.
[ ] 5,000 pounds.
[ ] 2,000 pounds.
[ ] 500 pounds.

241. **If it requires a force of 125 pounds to slide a weight of 500 pounds across a floor, the coefficient of friction is**
[ ] 0.125.
[ ] 0.25.
[ ] 0.50.
[ ] 0.625.

242. **If you weigh 100 pounds and the coefficient of friction between your feet and the ice is 0.09, in order to slide you across the ice a boy must push on you with a force of**
[ ] 900 pounds.
[ ] 90 pounds.
[ ] 9 pounds.
[ ] 0.9 pounds.

243. **The maximum pull which a locomotive weighing 100 tons can exert when the coefficient of friction between the rails and the wheels is 0.2 is**
[ ] 2,000 tons.
[ ] 200 tons.
[ ] 20 tons.
[ ] 2 tons.

244. **If the coefficient of rolling friction is 0.01, the force with which an engine would be pulling, on a level track, to haul a train weighing 500 tons is**
[ ] 5 tons.
[ ] 50 tons.
[ ] 500 tons.
[ ] 1,000 tons.

245. **With what force can a locomotive weighing 30 tons pull before slipping if the coefficient of sliding friction is 0.2?**
[ ] 60 tons.
[ ] 30 tons.
[ ] 20 tons.
[ ] 6 tons.

246. The relationship between the coefficients of rolling and sliding friction is such that the coefficient of sliding friction is

☐ the same as the coefficient of rolling friction.
☐ greater than the coefficient of rolling friction.
☐ less than the coefficient of rolling friction.
☐ sometimes greater and sometimes less than the coefficient of rolling friction.

247. If the coefficient of iron sliding on iron is 0.2, the coefficient of iron rolling on iron is about

☐ 0.2
☐ 0.18
☐ 0.12
☐ 0.009

248. Efficiency is the

☐ ratio of input to output.
☐ ratio of output to input.
☐ ratio of work done on a machine to the work got from the machine.
☐ ratio of work lost in a machine to the work put into the machine.

249. If an effort of 50 pounds moving a body through a distance of 20 feet lifts a weight of 80 pounds a distance of 10 feet, the efficiency of the machine used is

☐ 50 per cent.
☐ 80 per cent.
☐ 90 per cent.
☐ 125 per cent.

250. If the work obtained from a machine is 300 foot pounds and the efficiency is 60 per cent, the work put in is

☐ 180 foot pounds.
☐ 240 foot pounds.
☐ 360 foot pounds.
☐ 500 foot pounds.

251. The mechanical equivalent of a calorie is

☐ 778 gram meters.
☐ 724 gram meters.
☐ 427 gram meters.
☐ 247 gram meters.

252. A force is measured in

☐ centimeters.
☐ watts.
☐ horse power.
☐ grams.

253. **The force of friction is measured in**
[ ] foot pounds.
[ ] joules.
[ ] ergs.
[ ] pounds.

254. **A force is measured in**
[ ] dynes.
[ ] kilometers.
[ ] liters.
[ ] miles.

255. **A force is measured in**
[ ] kilowatts.
[ ] ergs.
[ ] poundals.
[ ] foot pounds.

256. **The mechanical equivalent of a calorie is**
[ ] 4.19 joules.
[ ] 7.78 joules.
[ ] 41.9 joules.
[ ] 77.8 joules.

257. **At very high speeds fluid friction is usually in proportion to the**
[ ] square root of the velocity.
[ ] square of the velocity.
[ ] cube of the velocity.
[ ] velocity.

258. **The amount of heat required to raise the temperature of 5 pounds of water 5 degrees Fahrenheit is**
[ ] the same as the heat required to raise the temperature of 5 pounds of iron 5 degrees Fahrenheit.
[ ] greater than that required to raise the temperature of 5 pounds of iron 5 degrees Fahrenheit.
[ ] less than that required to raise the temperature of 5 pounds of iron 5 degrees Fahrenheit.
[ ] 10 British Thermal Units.

259. **The number of calories required to raise the temperature of 5 grams of water 90 degrees centigrade is**
[ ] 85.
[ ] 95.
[ ] 180.
[ ] 450.

260. **A gravitational unit of force is called a**
[ ] joule.
[ ] pound.
[ ] watt.
[ ] kilometer.

261. A gravitational unit of force is called a
☐ gram.
☐ dyne.
☐ poundal.
☐ erg.

262. An absolute unit of force is called a
☐ pound.
☐ liter.
☐ watt.
☐ dyne.

263. An absolute unit of force is called
☐ an erg.
☐ a kilowatt.
☐ a poundal.
☐ a joule.

264. A gravitational unit of energy is called
☐ an erg.
☐ a joule.
☐ a foot poundal.
☐ a kilogram meter.

265 An absolute unit of energy is called a
☐ foot poundal.
☐ foot pound.
☐ gram centimeter.
☐ hectogram.

266. A force of 5 grams is nearly equal to
☐ 4,450 dynes.
☐ 4,900 dynes
☐ 4,400 dynes.
☐ 4,950 dynes.

267. A force of 100 pounds is nearly equal to
☐ 3,261 poundals.
☐ 2,316 poundals.
☐ 3,219 poundals.
☐ 2,361 poundals.

268. A force of 1,000 poundals acting for 10 seconds on a mass of 100 pounds will give it a velocity of
☐ 100 feet per second.
☐ 1,000 feet per second.
☐ 1,100 feet per second.
☐ 10,000 feet per second.

269. The force required to give a mass of one kilogram a velocity of 100 centimeters per second in 50 seconds is

[ ] 5,000 dynes.
[ ] 3,500 dynes.
[ ] 3,000 dynes.
[ ] 2,000 dynes.

270. Work is measured in

[ ] joules.
[ ] coulombs.
[ ] farads.
[ ] frictional units.

271. Work is measured in

[ ] watts.
[ ] ergs.
[ ] dynes.
[ ] kilograms.

272. Work is usually measured in

[ ] poundals feet.
[ ] foot poundals.
[ ] poundals.
[ ] kilogram feet.

273. Work is usually measured in

[ ] grams.
[ ] centimeters.
[ ] centimeter grams.
[ ] gram centimeters.

274. The amount of work done in lifting a book weighing two pounds to the top of a table three feet high is

[ ] 6 foot pounds.
[ ] 5 foot pounds.
[ ] $1\frac{1}{2}$ foot pounds.
[ ] 1 foot pounds.

275. The amount of work done in lifting a weight of 5 kilograms a distance of 10 meters is

[ ] 50 kilogram meters.
[ ] 15 kilogram meters.
[ ] 5 kilogram meters.
[ ] 2 kilogram meters.

276. The top of a tank is 10 feet above the source of water supply and the bottom of the tank is at the same level as the source. The amount of work done when a man fills the tank by pouring in 1000 pounds of water at the top is

[ ] 100 foot pounds.
[ ] 1,010 foot pounds.
[ ] 5,000 foot pounds.
[ ] 10,000 foot pounds.

277. **A man weighing 200 pounds pulls a box weighing 100 pounds along a floor for a distance of 100 feet. If the man exerts a pull of 20 pounds on the box, the work done equals**
[ ] 2,000 foot pounds.
[ ] 10,000 foot pounds.
[ ] 20,000 foot pounds.
[ ] 30,000 foot pounds.

278. **If a stone weighing 10 pounds is lifted from the ground and placed on a post 4 feet above the ground, its energy has been increased by**
[ ] 140 foot pounds.
[ ] 40 foot pounds.
[ ] 14 foot pounds.
[ ] 6 foot pounds.

279. **If a weight of 10 kilograms is placed on a shelf 5 meters from the floor, its energy has been increased by**
[ ] 50 ergs.
[ ] 15 farads.
[ ] 5 coulombs.
[ ] 5,000,000 gram centimeters.

280. **If a force of 3,216 poundals acts through a distance of 10 feet, the amount of work done is**
[ ] 32,160 foot pounds.
[ ] 32,160 ergs.
[ ] 321.6 milhenries.
[ ] 1,000 foot pounds.

281. **If a force of 1,960 dynes acts through a distance of 10 centimeters, the amount of work done is**
[ ] 1,960 joules.
[ ] 196 ergs.
[ ] 20 gram centimeters.
[ ] 19.6 dyne centimeters.

282. **If a pile driver weight of 2500 pounds is dropped 10 feet onto the head of a pile, it has an amount of energy equal to**
[ ] 25,000 ergs.
[ ] 25,000 foot pounds.
[ ] 250 foot pounds.
[ ] 25,000 dynes.

283. **The energy possessed by a 4000 pound automobile running 90 miles per hour is about**
[ ] 240,000 foot pounds.
[ ] 352,000 foot pounds.
[ ] 460,000 foot pounds.
[ ] 481,592 foot pounds.

284. The mechanical equivalent of heat equals

[ ] 887 foot pounds per B.T.U.
[ ] 878 foot pounds per B.T.U.
[ ] 787 foot pounds per B.T.U.
[ ] 778 foot pounds per B.T.U.

285. The mechanical equivalent of heat shows the

[ ] value of heat in British Thermal Units.
[ ] value of one degree of heat in foot pounds.
[ ] amount of coal required to give one British Thermal Unit.
[ ] numerical relation between a unit of heat and a unit of work.

286. A definition of specific heat is the number of British Thermal Units required to

[ ] raise the temperature of one pound of water one degree Fahrenheit.
[ ] change one pound of water into one pound of steam without a change in temperature.
[ ] raise the temperature of one pound of a substance one degree Fahrenheit.
[ ] melt one pound of a substance.

287. Specific heat is the number of British Thermal Units given out or absorbed in

[ ] raising the temperature of one gram of a substance one degree Fahrenheit.
[ ] lowering the temperature of one pound of a substance one degree Fahrenheit.
[ ] raising the temperature of one pound of a substance one degree centigrade.
[ ] lowering the temperature of one gram of a substance one degree Fahrenheit.

288. Specific heat is the number of calories given out or absorbed in

[ ] lowering the temperature of one pound of a substance one degree Fahrenheit.
[ ] raising the temperature of one pound of a substance one degree Fahrenheit.
[ ] raising the temperature of one pound of a substance one degree centigrade.
[ ] lowering the temperature of one gram of a substance one degree centigrade.

289. Specific heat is the number of British Thermal Units given out or absorbed in

[ ] raising the temperature of one gram of a substance one degree centigrade.
[ ] lowering the temperature of $\frac{1}{2}$ pound of a substance 2 degrees Fahrenheit.
[ ] raising the temperature of one pound of a substance one degree centigrade.
[ ] melting one pound of ice without changing its temperature.

290. Specific heat is the number of calories required to raise the temperature of one

[ ] gram of a substance one degree centigrade.
[ ] gram of water one degree centigrade.
[ ] cubic centimeter of a substance one degree centigrade.
[ ] liter of a substance one degree centigrade.

291. If the specific heat of aluminum is 0.2, the amount of heat required to raise the temperature of 20 pounds of aluminum from 40 degrees Fahrenheit to 100 degrees Fahrenheit is

[ ] 2,400 B. T. U.
[ ] 1,200 B. T. U.
[ ] 240 B. T. U.
[ ] 160 B. T. U.

292. If 100 grams of gold at 100 degrees are placed in 100 grams of water at 20 degrees and the resulting temperature is 23 degrees, the specific heat of gold is

[ ] 0.015.
[ ] 0.024.
[ ] 0.028.
[ ] 0.039.

293. If the specific heat of iron is 0.1 and equal weights of water at 80 degrees and iron at 20 degrees are mixed, the resulting temperature will be

[ ] 15.0.
[ ] 40.0.
[ ] 74.5.
[ ] 160.0.

294. If 200 grams of brass, having a specific heat of 0.09, are heated to 200 degrees and placed in 100 grams of water at 0 degrees, the resulting temperature will be

[ ] 100.2.
[ ] 54.7.
[ ] 30.5.
[ ] 18.9.

295. The maximum speed at which the driver of a car weighing 2000 pounds can go around a curve of 80 foot radius, if the coefficient of friction between his tires and the road is 0.3, is

[ ] 24.8 miles per hour.
[ ] 20.5 miles per hour.
[ ] 18.9 miles per hour.
[ ] 16.3 miles per hour.

296. If 10 grams of water fall 854 meters, it will be heated about

[ ] 2.0 degrees.
[ ] 10.9 degrees.
[ ] 20.0 degrees.
[ ] 85.4 degrees.

297. Small wheels are used on automobiles because they

[ ] reduce friction.
[ ] increase friction.
[ ] reduce the danger of overturning.
[ ] cost less than large wheels.

298. If a gallon of gasoline contains 150,000 British Thermal Units, it has enough energy to raise an automobile weighing 3,000 pounds a distance of

[ ] 527.4 feet.
[ ] 839.2 feet.
[ ] 1754.8 feet
[ ] 7.4 miles.

299. A stone 4 feet long, 3 feet wide, and 2 feet thick is placed on its side. If the stone weighs 3,000 pounds, the smallest amount of energy which must be used to place it on its end is

[ ] 3,708 foot pounds.
[ ] 4,025 foot pounds.
[ ] 4,500 foot pounds.
[ ] 6,000 foot pounds.

300. Tangential friction

[ ] does not exist in fluids in motion.
[ ] does exist in fluids at rest.
[ ] between two fluid surfaces is due to viscosity.
[ ] between two fluid surfaces is not due to viscosity.

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CHAPTER II

DEFINITION AND LIMITATIONS OF THE PROBLEM

Let us consider three factors which may be the cause of the decreasing enrollment in physics:

1. The proper subject matter is not being taught in our schools.

2. We are not using correct methods of teaching.

3. The inception of instruction is not at the proper level.

Educational publications have contained, for many years, numerous articles dealing with these factors. As far back as the days of William James,[1] we were told we should begin with the child's native interests and present to him objects that have immediate connection with these.

Many of the educational articles dealing with the above factors have, in general, been deductive in nature. This is a problem which cannot be solved by simply sitting down and thinking about it. The solution attempted here is both objective and inductive.

This dissertation will deal mainly with the proper levels for the inception of instruction, although the selection of proper subject matter and the use of correct methods of teaching will be briefly considered.

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[1] William James, Talks to Teachers on Psychology, Henry Holt and Company, New York, 1901, p.95.

In establishing grade levels or starting points for the subject of friction, a foundation has been laid which may serve as an initiation for a new and better method of teaching science.

The evidence submitted in this dissertation that there is a real difference in knowledge, as far as the subject of friction is concerned, between boys and girls may lead to the institution of a type of teaching which will not exclude girls from certain areas of science activity.

The form used for determining the main scientific interests of students occurs on the first page of the pamphlet containing the test on friction. This form is used in an attempt to learn the major interests of both boys and girls in the field of science. If the teacher will substitute for his own interest in the subject matter, the major interests of his students, the rapidly decreasing enrollment in physics may be substantially checked.

This investigation tends to show that, although certain portions of the concept of friction may be learned on several grade levels, there is a difference in the number and complexity of the associations which makes possible a plan for a rational gradation.

The main problem is an attempt to ascertain what portion of the concept, "The energy consumed in the motion of one body across the surface of another is usually transformed into heat", has been, may be, or should be learned by pupils of grades VII, VIII, IX, X, XI, and XII. The study will involve an objective determination of that portion of the concept already acquired, an attempt to ascertain the levels on which adaptations for certain portions of the concept may

exist, and a determination of the questions, problems, and difficulties which both teachers and pupils actually face and recognize.

Several relevant minor problems appeared during the investigation. These are formulated in the following statements:

1. As judged by the knowledge of friction, are country children superior to city children ?

2. Should girls be taught friction on the same level as that used in teaching boys ?

3. Is it true with regard to knowledge of friction, as it is with many other things, that some IXth grade students know as much as the average XIIth grade student ?

4. Is there a period in the development of the child where scientific observation is accentuated as judged by the knowledge of friction ?

5. Do the scientific interests of children, as regards subject matter, change as they advance to higher grade levels ?

6. In what applications of science are children on the different grade levels most interested ?

CHAPTER III

SUMMARY OF PREVIOUS INVESTIGATIONS

Haupt[1] raises an issue regarding the aim of science teaching. He states that the aim may be of the "moral, vocational, aesthetic, civic, ethical, and spiritual" type or that it may be of the objective type with the statement of goals of attainment, such as, "Energy is not destroyed but is changed into other form."[2]

Haupt selected light as a manifestation of energy which existed in an extensive range of energy transformations. Six textbooks and two courses of study were analyzed to obtain statements concerning light. 319 separate statements resulted with a frequency of 513. A true-false test, an old type composition test, and a completion test were composed, mainly from these statements. These tests were given to children of Grades I to VI. As a result of this investigation, Haupt drew pertinent conclusions as follows : "The objective type of aim can be used to select elements of learning throughout a range of grade levels. The same kind of learning is not to be expected from the children of all grade levels. There is a difference in the complexity of the associations

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[1] G.W. Haupt, A Philosophy of Science Teaching in an Elementary School, Teachers College Contributions to Education, Number 633, Teachers College, Columbia University, New York, 1935, p.2-4.

[2] Whenever the objective type of aim is mentioned in this thesis, it is understood that it is used with the above meaning.

and it is this difference which gives key to a plan of rational gradation. The data indicate the presence of the same kind of mental activity on all the grade levels studied."

Haupt[1] also states that there is no experimental evidence that the content from biological sciences is less difficult for children than content from the physical sciences and therefore better adapted to the lower grades of the elementary school.

Haupt suggests further study on higher grade levels and states that it would be well to show some of the relations of other topics which are often considered too narrowly by teachers on all grade levels.

Hartman and Stephens[2] attempted to determine the relative "pleasure values" of principles of physics. A test was compiled by an analysis of the six most commonly used textbooks of physics. The list of 144 principles of physics included in the test contained 38 principles for mechanics, 19 for heat, 50 for electricity, 8 for sound, and 29 for light. The test was given to 252 pupils in six Pennsylvania cities.

The pupils were asked to indicate their reaction to each question as follows: pleasure-extreme (3), moderate (2), slight (1), neutral (0); aversion ,slight (1), moderate (2), and extreme(3). "The mean pleasure value of each principle was calculated readily by summing algebraically its rating in all papers and dividing that total by the number of persons answering the item."

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[1] G.W. Haupt, op. cit., p.103-105.

[2] G.W. Hartman and Dean T. Stephens, "The Optimal Teaching Sequence for Elementary Physical Principles Based on a Composite Scale of Pleasure-value and Difficulty of Insight", The Journal of Educational Psychology, XXVIII (September,1937), pp.414-436.

Hartman and Stephens[1] concluded as follows: "The mean pleasure value for all principles was .94±.035. The range was between 1.931 and 0.064. The descending order of the mean pleasure indexes for the different physical divisions ran as follows: light, 1.101; mechanics, 1.054; heat, 1.007; sound, 1.004; and electricity, .718." The pleasure-value of short-sentence principles was greater than that of statements of more than average length. The chances were found to be 99.63 in a hundred that the pleasure value of boys is greater than that of girls.

Carter[2], in determining the mathematical abilities in high-school physics, decides that, with the exceptions of computational ability and a variability of performance on some tests, the differences between boys and girls are not great enough to be considered very significant. The wide range of reading ability may be of importance with respect to the time which must be spent by different pupils in mastering a given assignment. Carter concludes with the statement that the fundamentals of mathematics are not thoroughly enough mastered by high school students to enable them to apply these fundamentals in the field of physics.

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1. G.W. Hartman and Dean T. Stephens, op.cit., pp.414-436.

2. W.R. Carter, Doctor's Dissertation, "A Study of Certain Mathematical Abilities in High-School Physics", The Mathematics Teacher, XXV (October, November, and December,1932), pp.313-331, 388-419, and 451-469.

The Progressive Education Association's Committee on the Function of Science in General Education[1] suggests the use of a much wider range of material and the importance of teaching science so as to meet the everyday needs of youth.

J.B. Coleman[2] states that teachers of physics are more interested in the subject matter than they are in the students. He[3] also states that the proportion of boys to girls in physics is more than that of two to one.

Powers[4] recommends that science teaching be so conducted that students acquire the ability to interpret their environment, utilize the findings of science which have application in their own experience, and acquire an understanding of an ability to use the methods that have been used by creative workers in the fields of science.

An article in School Science and Mathematics[5] states:

"The average college graduate teaches physics in the high school as it was taught to him in college. The course given is, therefore, ecbatic rather than telic. It gives the student little knowledge of his milieu. It is a serious mistake to place in the hands of the average commercial or non-college student a text of the type usually written by a college instructor."

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1. Progressive Education Association, Commission on Secondary School Curriculum, *Science in General Education*, D. Appleton-Century Company, Inc., New York, 1938, p.12.
2. John Burgess Coleman, *Present Practice and Opinion in the Teaching of Physics in the Public High Schools of the United States*, unpublished Master's Thesis, Boston University, Boston,1934, p.2.
3. Ibid. p.38.
4. Samuel Ralph Powers, "Educational Values of Science Teaching", *Teachers College Record*, XXXII (October,1930), pp.17-33.
5. Ralph B. DeLano, "The Socialization of High School Physics", *School Science and Mathematics*, XXXIV, Number 5 (May, 1934), p.522.

Efron[1] conducted an investigation which was undertaken to discover the salient characteristics of the teaching of physical sciences in the secondary schools of the United States, France, and Soviet Russia; to evaluate and compare the types of teaching procedures observed; and to determine the implications for physical science teaching in the United States. He analyzed the national system of education of each country by studying the content and organization of the courses of study, the training of science teachers, the nature of tests and examinations, the character of textbooks, the methodology of science teaching, the conduct of extracurricular science work, and the design and utilization of science equipment.

The study made by Efron was descriptively analytical, since no tests could be administered which would have statistical validity as a basis for comparing subject matter accomplishments. An interpretative-philosophic approach was used.

Efron states that there is no agreement among American Science teachers as to just what is really important in the science course of study and whether it is facts, theories, habits, skills, or certain concomitants which ought to be stressed. He thinks that the tendency, at the moment, appears to be in the direction of emphasizing the method and function of science rather than its formal content.

In regard to foreign schools, Efron states that the concentric or spiral arrangement in the schools of both France

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1. Alexander Efron, The Teaching of Physical Sciences in Secondary Schools, Teachers College Contributions to Education,Number 725, Columbia University, New York, 1937, p.279.

and Soviet Russia is commendable. He says that much can be learned from the French emphasis on clarity of exposition and care in oral and written expression. In regard to the Soviet program, Efron[1] states that the Soviet motivation technique, which draws its strength from the technical and industrial life that surrounds and permeates the school at every point, constitutes an innovation in science teaching which is deserving of further study.

Schindler[2] tries to ascertain the extent to which pupils in high-school physics memorize textbook statements without grasping their meanings or developing understanding of related phenomena. Six textbooks were analyzed and two types of test items were constructed. One of these types tested memorized statements only. The other type of test items were so constructed that they could not be answered by simply supplying or recalling a stereotyped textbook statement.

Schindler's conclusions follow: "Stereotyped textbook statements in the subject matter of high-school physics are memorized, on the average, by about 70 per cent of the pupils, but only 17 per cent of all pupils develop a 'satisfactory' understanding of these statements. If the class recitation is concerned chiefly with the repetition of textbook statements, the teacher cannot tell whether or not the pupils have developed or are developing the understanding which they need to develop, if the statements are to serve them in the situations and for the purposes described by the objectives of instruction."

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1. Alexander Efron, op. cit., p.279.
2. A.W. Schindler, The Extent of Rote Learning in Certain Units of High-School Physics, unpublished Doctor's Dissertation, Iowa State University, Iowa City, Iowa, 1934.

Clemensen[1] developed a series of study outlines by analysing professional literature, scientific periodicals, physics textbooks available, and questions suggested by pupils. The subject-matter was formulated into direct questions, each containing "one idea". The questions were constructed so as to develop interests, attitudes, and habits as well as concepts, knowledges, and skills.

These study outlines were used with 850 pupils arranged in an outline group, a non-outline group and an outside control group. Standardized tests were given at the end of the semester. Conclusions were as follows: "Most physics students appreciate learning something in an attractive, organized manner rather than being entertained." The outline groups did better work and developed better study habits.

Croxton[2] tested the ability of pupils to generalize in science. He found that the range in percentages of pupils who were able both to generalize and to apply was from 5 for Grade I to 55 for Grade VIII. He states that the ability to generalize, to apply generalizations, and to do both, increased with the grade.

The National Society for the Study of Education[3] suggests that the objective of education is the enrichment of life through participation in a democratic social order and plans the organization of the subject matter around generalizations rather than around the laws of science.

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[1] J.W.Clemensen, "Study Outlines in Physics", Science Education, XVI (December, 1932), pp.453-461.

[2] W.C.Croxton, "Pupils' Ability to Generalize", School Science and Mathematics, XXXVI, Number 6(June,1936), pp.627-634.

[3] National Society for the Study of Education, Thirty-first Yearbook, Part I, A Program for Teaching Science, Public School Publishing Company, Bloomington, Illinois,1932, p.42.

Hurd[1] made a study to determine the relative "value of combined study and recitation periods in the class room as opposed to study being carried on outside the class room."

The subjects of this investigation were divided into two groups. The first group contained 58 pupils with an I.Q. of 107.7 (S. D.± 9.1, range 90-130). The second group contained 61 pupils with an I.Q. of 108.7 (S.D.± 8.1, range 91-127). The first group met 7 periods per week; the second group met 10 periods per week. With the latter group, "no outside lessons were assigned, all study work being taken care of in the class periods." The first group were assigned lessons to prepare outside the class periods.

Hurd found that the mean scores of the two groups were respectively 78.4 (S.D.± 17.9) with a range of 51-126 points, and 81.0 (S.D. ± 18.7) with a range of 44-126 points. "One fails to note any clear advantage or disadvantage of the ten-period plan as compared with the seven-period plan."

Browning[2] attempted to compare conventional procedures in the teaching of physics with the use of a workbook. He concludes that the workbook or a work-sheet method gave slightly superior results, especially with superior pupils. He also states that pupils of less than normal mental age profit most when taught by the recitation method.

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1. A.W. Hurd, "Suggestions on the Evaluation of Teaching Procedures in High School Physics", School Science and Mathematics, XXVII, Number 5 (May, 1927), pp.220-226.
2. C.A.Browning, "A Work-sheet for High-School Physics", Science Education, XVIII (February, 1934) pp.37-41.

Miller[1] conducted an experiment with 600 pupils to determine the extent to which the pupils in the public high schools acquired the common facts and information required in an elementary course in physics, to find what effect the size of the class has on the scores, to compare the achievements of the pupils of the different years in which physics was taught, and to make a study of the relationship that existed between teachers' marks and the scores attained in an objective test.

He concluded that the pupils in the public high schools, in which the investigation was conducted, have not acquired the facts given in 5 widely used text-books, that the size of the class has no consistent effect on the score attained, that the median test-scores of the fourth-year, the third-year, and the second-year pupils were respectively : 27.6, 22.0, and 27.6, and that the marks assigned by the teachers and the scores attained in the test do not bear a close relationship.

In an article in School Science and Mathematics,[2] the statement is made that we should stop the decreasing enrollment in physics by showing that physics is the easiest of all subjects with which to learn to think, that we use physics in every move we make, and that physics helps us to judge most of the materials and machinery we buy.

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[1] P.S. Miller, "A Quantitative Investigation of the Efficiency of Instruction in High School Physics", Journal of Educational Research, XIX, February, 1929, pp.119-127.

[2] J.T. Peters, "The Physics Teacher Faces His Problems", School Science and Mathematics, XLI, Number 6 (June, 1941), p.562.

Watson[1] tried to determine the relative practical values of devices discussed in text-books of high school physics, as indicated by the opinions of adults. He compiled a list of 174 devices described in 3 well known physics texts. Pupils who were studying in 75 high schools in Kansas, were asked to have their parents fill out the questionnaire. 659 replies were received.

Watson concluded that there are numerous items in physics texts which possess little knowledge value and that there are numerous pertinent items of recognized value which are not included. He also states that occupational life makes less difference than has been commonly supposed in the selection of subject-matter for high school courses in physics. There is a high correlation of .90 among farmers, mechanics, professional men, merchants, and women in their choices of worth-while items for a course of study in physics.

A portion of Watson's list, in the order of importance, follows: Thermometer, ice cream freezer, kitchen range, heating stove, door lock, sewing machine, window shade roller, oil stove, regulation of a clock, kerosene lamp, fever thermometer, rifle, cream separator, spectacles, water faucet, crowbar, block and tackle, automobile tires, automobile jack.

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1. C.W. Watson, "A Critical Study of the Content of High School Physics with Respect to its Social Value," The School Review, XXXIV, (November, 1926), pp.688-697.

Hughes[1] reported an investigation to compare the intelligence of pupils studying the subject of physics in schools of different sizes, to compare the achievement of these pupils in physics, and to study the effect of the training of the teachers on the achievement of these pupils. Sixteen hundred pupils and one hundred teachers in 29 high schools were involved in the experiment. Three tests containing a total of 101 items were administered.

Hughes concludes that the average I.Q. of the pupils in schools with enrollments of more than 550 pupils is about 5 points above that of the smaller schools. Above 550 pupils, "the median I. Q. of the pupils enrolled remains relatively constant." The size of the school seems to have but little effect on achievement. The achievement of girls is inferior to the achievement of boys. "As physics is now taught, a requirement of the subject of girls as made in many schools seems unjustifiable. College courses designed specifically for the training of teachers for the teaching of physics in the secondary school are very much needed."

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[1] J.M. Hughes, Doctor's Dissertation, "A Study of Intelligence and of the Training of Teachers as Factors Conditioning the Achievement of Pupils", The Journal of Educational Psychology, XVI, April, 1925, pp.217-231.

Peters[1] made a significant study in which he determined the relative effectiveness of two types of organization of subject-matter in high school physics: (1) the (deductive) organization found in the "typical textbook" in which the statement of a principle or generalization is followed by applications; and (2) an (inductive) organization in which the applications precede the statement of a principle or generalization.

Peters concluded, as a result of this experiment with 177 students, that the total gain of the class was greater in every case when the pupils were taught by the inductive method. "Pupils do not get an idea of the applications as well as they should, when the typical text-book organization is used, or as well as they do when the reorganized material is used."

Carpenter[2] determined the effects produced by studies in general science and biology upon success in physics and chemistry. He found that pupils who had studied general science 5 or 6 terms made consistently higher median scores in physics and chemistry than did those who had studied general science for less than 5 terms. He also learned that pupils who had studied general science made higher median scores in physics and chemistry than did those who had studied elementary biology.

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[1] C.J. Peters, "An Evaluation of a Reorganization of the Present Core of Subject-Matter in High School Physics", School Science and Mathematics, XXVII, Number 2 (February, 1927), pp.172-182.

[2] H.A. Carpenter, "Results of a Three-year Science Sequence in Junior-High-School Grades", Science Education, XVII (October, 1933), pp.183-192.

Ebel,[1] in determining the effect of irrelevant data in physics test problems, introduced irrelevant data among problems, relating to mechanics and heat, which were found in the Iowa Every-Pupil Test in Physics. He concludes as follows : "The correlation between achievement test scores and scores on the standard problems was .719 ± .026, between achievement test scores and scores on the irrelevant data problems was .714± .027, and between scores on the standard problems and scores on the irrelevant data problems was .921 ±.008. Evidently the inclusion of irrelevant data in the physics problems did not change, and hence could not improve the characteristics of the test.

Ralya[2], in an investigation of accomplishment in high-school physics, made an anlysis of the five most popular textbooks of high-school physics as far as the subject of mechanics was concerned. From this information he constructed a battery of 18 unit tests containing 585 items which were administered to about 500 pupils in eleven different schools. The tests were administered by the regular classroom teacher.

Ralya states in his results that knowledge of the factual was sometimes considerably greater than understanding the principle behind the factual, that success in recognizing a verbal statement as true did not always involve understanding it and the ability to apply it, and that success in reproducing or recalling a formula was sometimes much greater than the success in solving problems.

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1. R.L. Ebel, "Some Effects of Irrelevant Data in Physics-Test Problems", School Science and Mathematics, XXXVII, Number 3, (March, 1937), pp.327-330.
2. L.L. Ralya, Doctor's Dissertation, "An Investigation of Accomplishment in High School Physics by Means of Diagnostic Tests", Phi Bulletin (Phi Delta Kappa), University of Wisconsin, Madison, Wisconsin, XII (June, 1935), pp.2-6.

Beauchamp[1] tried to determine whether the progress of pupils in elementary physical science is constant, that is, whether the relative positions of the pupils in a class remain unchanged; and whether the mental ability of the pupils, as determined by intelligence tests, furnishes a safe guide for classifying the pupils into slow, medium, and fast groups.

He draws conclusions as follows:

1. "The relative progress of the pupils in a class is not constant." Most pupils change their relative positions in accordance with the influence of numerous factors, many of which are potentially under the control of the teacher.

2. The results "would seem to indicate that other factors are more potent in influencing the rate of progress than 'brightness' as measured by the intelligence score, when the time allowance for all pupils is the same. A much higher correlation was found between reading ability and the rate of working, than between general intelligence and the rate of working."

Downing[2] attempted to ascertain "what increase in knowledge of the several science subjects is shown from year to year of the high school." He examined about 3000 students in 6 high schools and found that knowledge of physical geography, chemistry, and biology was not affected to any great extent by out-of-school contacts. He states that general science contributes considerably to knowledge of physics. "Physics instruction for Juniors and Seniors contributes notably to their understanding of the subject."

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1. W.L. Beauchamp, "An Investigation of Pupil Progress in Elementary Physical Science", Studies in Secondary Education, II, Supplementary Monographs, Number 26, The University of Chicago, (February, 1925), pp. 14-32.
2. E.R. Downing, "High School Science Instruction Compared to Out-of-School Experiences", School Science and Mathematics, XXVIII, Number 2 (February, 1928), pp. 148-153.

Noll[1] states that the emphasis on use seems to carry with it a disregard for the boundaries of chemistry, biology, physics, etc. as such, and to encourage the fusion and intermingling of all sciences as they add to our understanding of the world about us.

Gould[2] says there are three types of science courses in operation throughout the country. First, there is the Special Field Course in Physics, Chemistry, or Biology planned to explore one of the natural sciences for the purpose of general education. Second, there is the General Field Course which draws its material from two or more of the natural sciences. Third, there is the Integrating Course which is organized around problems of general interest to the majority of students, and which selects its material from any major field that can serve its purpose.

Hurd[3] conducted an investigation with students in over 20 high schools. He found that pupils having a liking for physics made higher achievement ratings, that data favor boys over girls, that twelfth-grade pupils did better than eleventh-grade pupils, that data favor those who come from large families, and that data favor those who sleep at least 9 or 10 hours a night.

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1. V.H. Noll, "What about Integration in Science?" School Science and Mathematics, XLI, Number 3 (March,1941), p.241.

2. Arthur L. Gould, "Trends in Science Instruction", The Boston Science News, I, Number 9 (January, 1940), p.4.

3. A.H. Hurd, "What Factors Make for Good or Poor Achievement in Science?", Science Education, XX (February, 1936), pp.4-7.

Walter[1] conducted a study to determine the relative values of the individual manual laboratory method, the individual-no-manual method, and the demonstration method, with respect to ability to observe and remember and ability to think.

He concluded that the individual-no-manual method seems to be best adapted to drill work where the pupil sees easily the meaning of the problem before he performs the exercise. The teacher-demonstration seems most appropriate where information is to be gained from the exercise.

Rowland[2] asserts that the one main force which has been actuating each successive stage in the growth of physics teaching is the desire to make knowledge of natural phenomena serve the needs of mankind. During the nineteenth century, emphasis was placed upon mental discipline, college preparatory aim, and mathematical and abstract knowledge. In the twentieth century, the individual is catered to so that he may serve society by raising his competency to the highest possible level.

Dyer[3] tested the relative value of a developmental-demonstration method and a laboratory method. He found that the demonstration method was better for immediate and delayed recall, but that there is very little difference in the relative efficacy of the two methods in providing for permanency for realizations once established.

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1. C.H. Walter, "The Individual Laboratory Method of Teaching Physics When No Printed Directions Are Used", School Science and Mathematics, XXX, Number 4, (April, 1930), pp.429-432.
2. Robert James Rowland, History and Trend of the Teaching of Physics in the Secondary Schools of the United States, unpublished Master's Thesis, Boston University, Boston, 1931, pp. 107-110.
3. J.H. Dyer, Doctor's Dissertation, University of Pennsylvania, Philadelphia, 1927.

Pettit[1] made a topical analysis of 13 science text books. He says that no complete units were common to all texts and that 29 units appeared in only one text. "Of the total of 650 concepts appearing in all the texts, only 86 were found to be common to 3 or more texts."

Pettit also analyzed science books in an attempt to ascertain what information was taught in the 7th, 8th, and 9th grade levels. "Light as an area was used in two out of four books in the 8th and 9th grade levels, but was not considered to be so good at the 7th grade level. The air unit was used in four out of five 7th grade series and three out of four ninth grade series, but in only one out of four eighth grade books."

In his analysis of five 7th grade texts, Pettit states that no complete units were found to be common. Two units were common to three texts, five units appeared in two texts, and twenty-nine units appeared in only one text.

In the 8th grade, the maximum frequency of use of any single unit was three, and this occurred in the case of two different titles. Ten other unit titles were used in two texts only. Fourteen titles were used in single texts. In no case did a given unit appear in all four texts.

In the case of the 9th grade, "The low degree of standardization of the content for graded junior high science is shown by the fact that only four units were common to three texts, and only eight other units were common to two texts. The remaining twenty units were used only once by the several authors.

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1. Donald D. Pettit, "The Content of Junior High School Science", School Science and Mathematics, XL, Number 7 (October, 1940), p.643.

In this paper we have shown that there is little agreement among the authors of the several books as to what content should be included at the various grade levels and in the definite subject."

Carpenter[1] made a study to determine the relative success in chemistry and physics of pupils who have previously studied general science with that of pupils in the same subjects who have previously studied biology.

He found that the median scores of the groups who had preceded their study of physics and chemistry by a study of general science ranged from 1 to 10 points higher than the median scores of the groups who had preceded their study of physics or chemistry by a study of biology.

Dr. Billig[2] states that there is need of extended study of grade placement of content. VanderPloeg[3] and others, in a research investigation, found that there was little agreement among authors as to what content should be included at the various grade levels.

Lupone[4] says, "Yet, if one examines our better courses of study, one will discover no generally adopted plan or sequence of areas to be studied. The facts seem to indicate that no criteria

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1. H.A.Carpenter, "Success in Physics and Chemistry in Relation to General Science and Biology", Science Education, XIV, May, 1930, pp.589-599.
2. F. Billig, Thirty-First Year Book, Part I, A Program for Teaching Science, Public School Publishing Company, Bloomington,Illinois, 1932, Chapter 11, pp.163-177.
3. E.P.VanderPloeg, C.L.LeCocq, and O.F.Huffman, What Agreement Exists,If Any,Among the Various Authors as to What Should Be Included in Seventh,Eighth, and Ninth Grade Science, unpublished Master's Theses, State University of Iowa, Iowa City,Iowa,1939.
4. O.J.Lupone, "Some Problems That Must Be Answered in Elementary Science", School Science and Mathematics, XXXVIII, Number 6, (June, 1938), p.668.

have been determined for grade placement of topical material. 'The question what to teach' is still confronting our educators. And to add to the conflict there appears to be at the present time a controversy among the leaders and advocates of elementary science as to what should constitute the areas to be studied. If we claim we are directing our teaching towards growth in the intangibles, should we not be honest with ourselves and discover some means by which we can assure ourselves that there has been growth."

Professor J. O. Frank[1] analyzed 70 different courses dealing with the teaching of science. He states that these courses vary widely in about every way possible. He suggests the following courses for teachers of science:

"A. Teachers' Course in General Science. An undergraduate course dealing primarily with the broad general principles and the larger aspects of the subject matter of General Science. A course in professionalized subject matter, but with some attention to actual methods of instruction.

B. The Teaching of General Science. A course for graduates and undergraduates. Aims, selection and organization of subject matter, methods, texts, tests, etc.

C. Methods of Investigation of Problems Involved in the Teaching of Science. A strictly graduate course, dealing with methods of investigation and intended to find and train persons who have ability to contribute to science education."

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1. J.O. Frank, "The Need for Standards in Courses in the Teaching of General Science", School Science and Mathematics, XXVIII, Number 4 (April, 1928), p.380-388.

Brownell[1] states that an inexperienced high school teacher will inevitably teach in the high school the last thing studied in college; for this reason, let that last thing studied be a unifying course rather than a specialized one. "Without abandoning the special skill he has gained, he will come to feel the essential unity of the truths of science before he goes out to present them to the next generation. This will make of the graduate not only a better teacher but a better man or woman."

M.E. Herriott[2] presented a check list of 576 activities to a group of boys and girls of high school age and to a group of men and women from 37 occupations. As a result, he suggests the following order of large topics in a high school physics course:

BOYS	GIRLS
Magnetism and Electricity	Sound
Invisible Radiations	Light
Mechanics	Heat
Heat	Mechanics
Light	Magnetism and Electricity
Sound	Invisible Radiations

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1. H. Brownell, "The Psychology of High School Sciences and the Making of Science Teachers", School Science and Mathematics, XXVI, Number 5 (May,1926), pp.528-534.

2. M.E. Herriott, "One Influence in Out-of-School Activities in Determining the High School Physics Curriculum", School Science and Mathematics, XXVII, Number 1 (January, 1927), pp.56-60.

Curtis[1] made a significant study to secure data relative to the scientific interests of pupils enrolled in the ninth grade in small high schools and of adults living in small towns and in the country.

He found that the scientific interests are predominantly physical rather than biological, that the range of scientific interests of country girls and women is somewhat greater than that of country boys and men. "Men ask a greater percentage of questions about theories than the women. Interest in technical processes seems to increase with maturity. There is a surprising similarity in the interest lists of the boys and girls and of the men and women." Children were mainly interested in radio, electricity, plants, and the sun. The main interests of adults were insect pests, radio, electricity and plants.

Powers[2] prepared a list of uncommon words found to be most important on the basis of range and frequency of usage in science texts and in other reading material about scientific subjects. "Authors of text-books are using in their books many words which children will never see again after they have finished the required classroom work. Intelligence on the part of authors in regard to length and difficulty of vocabulary load is of paramount importance in the work of adapting the material of science text-books to the ability levels of the pupils for whom they were written."

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1. F.D. Curtis, "A Study of the Scientific Interests of Dwellers in Small Towns and in the Country", Peabody Journal of Education, V, (July, 1927), pp.22-34.
2. S.R. Powers, "A Vocabulary of Scientific Terms for High School Students", Teachers College Record, XXVIII, (November, 1926), pp.220-245.

The Subcommittee on Teacher Education[1] of the National Committee on Science Teaching points out the following defects :

"1. The teacher of science does not become in common practice an active force in the community of which he is a part.

2. The teacher of science has not been taught the processes that are vital to community life and the factors that make for social change.

3. The teacher of science does not recognize sufficiently interdependence of social welfare and scientific procedures and technology.

4. The teacher of science has not kept himself and his co-workers adequately informed about the recent scientific accomplishments immediately affecting personal and social welfare.

5. The teacher of science does not, and too often cannot, because of inadequacies in his education, deal with community goals for human betterment, or advise in their determination.

Competency for science teachers must include a realistic understanding of science and scientific method. This means : (1) thorough grounding in the scientific facts and principles in fields of special interest and enough acquaintance with those in other fields to make further study and evaluation of authorities possible; (2) comprehension of, and ability to apply, the methods of science used in different fields; (3) comprehension of the relationship between the different sciences and their applications in life-problems; (4) comprehension of how the sciences have affected, and can affect, personal and social life."

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1. S.R. Powers, "Preparation of Science Teachers to Contribute to General Education", School Science and Mathematics, XLII, Number 4, (April,1942), pp.315-324.

This dissertation is an attempt on the part of the writer to ascertain the interests and abilities of the pupils studied. By means of the objective type of aim he will attempt to avoid glittering and alluring generalities. Definite levels will be established for the transcendents studied. Knowledge of these interests and levels, when combined with concept levels of other major topics, may lead to a type of teaching which will eliminate from elementary and secondary schools such lecture methods as are adapted only to institutions of higher learning.

CHAPTER IV

METHOD OF CONSTRUCTION OF THE SURVEY TEST

The material used in the construction of the test is that found in textbooks of physics which were written for students below the college level. Textbooks published since 1895 were consulted and all the material on friction contained in these books was incorporated in the test. The list of textbooks was obtained from the catalogs and indexes in the libraries at Boston University, Harvard, Massachusetts Institute of Technology, and the Boston Public Library. Catalogs of book publishers were also consulted. Mimeographed lists of textbooks prepared by the Eastern Association of Physics Teachers were of great help. Twenty-eight texts were found. A list of these texts together with the date of publication may be found in Appendix A.

In studies where the objective type of aim is used, there can be but little variation in the subject matter regardless of the number of texts consulted. The fundamental laws of nature are unaffected by statements which man may make. A parallel study of the texts revealed that the same laws were treated in much the same manner in all of them. There were no attempts to adapt the subject matter to any particular environment. Since all the material found on friction was incorporated in the test, an objective selection of subject matter resulted.

TEST ON FRICTION

GENERAL OUTLINE

Friction	QUESTIONS
A. Nature and cause of friction	
1. Friction is the force which opposes the motion of one body across the surface of another.	10,13,40,54,99 148,149,253
a. Force	122,123
(1) Definition	7,9,41,165
(2) Units	93,252,254,255
(a) Gravitational	260,261
(b) Absolute	262,263
(3) Problems	147,183,181, 260,267,268, 269
2. Friction is mainly caused by irregularities in surface.	14,42,43,118, 171,188
a. Adhesion	102,212
B. Advantages and disadvantages of friction	
1. Places where friction is an advantage	
a. Grasping objects	3,63,105
b. Walking	64,106,111
c. Cloth, rope, and string fibers	60,61,108
d. Nails	6,66
e. Belts	5,70
f. Screws	
(1) Wood screws	44,71
(2) Jackscrews	190
(3) Steering worm	154

g. Wedge	69
h. Automobile clutch	160
i. Automobile brake	159
j. Between the surfaces of automobiles' tires and the road	157,158
k. Violin	100
l. Matches	103
m. Skating	2,155
n. Skiing	75
o. Sawing	57
p. Filing	73
q. Grinding	85
2. Places where friction is a disadvantage	
a. Skating	56
b. Sliding	55,109
c. Skiing	191,192
d. When moving objects	65,72
e. In machine bearings	89, 107
f. Drilling	87
g. Grinding	86
h. Screws	
(1) Wood screws	67
(2) Jackscrew	169
(3) Steering worm	153
C. How friction may be controlled	
(1) Methods of increasing friction	
a. Making surfaces rough	46,88,112,197

(1) Sand	38,151
(2) Resin	156
(3) Carpets	39,74
(4) Ashes	53
(5) Brakes	193
(6) Chains	19
b. Using soft or fine surface	
(1) Rubber	92, 98
(2) Dirt	4
c. Increasing pressure	91,194
d. Keeping surfaces dry	1,51
e. Changing rolling friction to sliding friction	8,80
2. Methods of reducing friction	
a. Making surfaces smooth	59,111
(1) Using bearing metals or jewels	
(a) Bearing metals	124,125,196
(b) Watch jewels	76
(2) Oiling, greasing and watering	11,34,52,101 126,131,134
(a) Oil	
(1 Viscosity of oil	202
(2 Effect of temperature on oil	16,82,132
(3 Fluid friction is internal friction	84,300
(4 Fluid friction is less than solid friction	35,172

(5 Fluid friction increases as the velocity increases	201,257
(b) Cup grease	133
(c) Graphite	152
(d) Paraffin	58
(e) Soap	68
b. Changing sliding friction to rolling friction	12,77,90,114 198
(1) Wheels	78,79,195,297
(2) Casters	15
(3) Roller bearings	116,127,130
(4) Ball bearings	115,128,129
D. Coefficients of friction	175, 176, 177
1. Coefficient of sliding friction	173, 236, 237
2. Coefficient of rolling friction	174,238,239
3. Relationship between coefficients	246,247
4. Problems relating to coefficients	
a. Sliding	241,242
b. Rolling	240, 243, 244, 245
E. Laws of friction	
1. More friction is required to set an object in motion than is required to maintain motion after starting is secured.	28,97,136 138,162,181 203
2. Friction is directly proportional to the pressing force	62,119,120 189,204
3. The extent of surface has little effect on friction unless the area of contact is so small that the surfaces cut into each other	17,18,29,48 83,180,186, 205
F. Heat results from friction	
1. Work	
a. Nature of work	23,94,95,139 168

b. Units used in measuring work	24,270,271,272 273
c. Problems involving work	274,275,276 277,280,281
d. Efficiency	
(1) Definition	22,121,135,137 150,161,163
(2) Problems	248,166,249, 250
2. Energy	
a. Nature of energy	25,26,27,30,31, 33,36
b. Kinds of energy	117,140,206, 207,208,209
c. Units used in measuring energy	210,211,213, 264,265
d. Problems involving energy	220, 278, 279, 282, 283, 299
3. Heat	
a. Nature of heat	49,104,221,222 223,224
b. Molecules	214,215,216, 217,218,219
c. Measurement of heat	
(1) Degrees of temperature	141,184, 288
(a) Fahrenheit Scale	142, 143, 144 182
(b) Centigrade Scale	225, 226,227
(2) British Thermal Unit	229,230,231
(3) Calorie	145,146,232
(4) Specific heat	286,287,288, 289,290

(5) Heat problems	233,234,235
(6) Heat equations	292,293,294, 295
4. Mechanical equivalent of heat and heat equivalent of work	
a. Heat is changed into work	32,47,179 185,285
b. Work is changed into heat	20,21,37,45,50 81,96,113
c. Numerical value of equivalent	251,256,284
d. Problems involving the mechanical equivalent	296, 298

The general outline was prepared by selecting the text which seemed to have the most complete discussion on the subject of friction and making a detailed outline of the material contained in this text. A check mark was placed after every concept. The next text was then read. New material found in the second text was added to the outline. A check mark was then placed after every concept found in the second text. This process was repeated until all the material contained in the twenty-eight texts had been added to the outline. The outline was completed when the material in the last text had been added. The check marks were used to show the relative frequencies with which each topic occurred.

The ratio of frequencies was used to determine the number of questions assigned to each topic. The material naturally fell into six major divisions :

A. Nature and cause of friction
B. Advantages and disadvantages of friction
C. How friction may be controlled
D. Coefficients of friction
E. Laws of friction
F. Heat results from friction

The above listed major divisions appear in all the texts consulted. The individual questions in the test were composed from statements found in the textbooks.

A check list of factual knowledge seemed to be the most objective methodfor securing the information desired. The

selection of a test with several wrong responses and one right response limits to a certain extent the tendency on the part of the pupils to guess. For this reason, a multiple-response test was considered better than a number of true-false statements.

The multiple-response type of test is superior to the written response form for work of this nature because the information can be secured rapidly and definitely. The multiple-response examination of students also increases the ease with which concrete tabulations may be made.

Since this is not a sampling test, the distribution of the subject matter among the test items was automatically determined by the analysis of the twenty-eight controlling textbooks. A test of three hundred items, each item having four responses, developed from this study. Preliminary administration of some of the test questions with a varying number of responses seemed to indicate that little of value could be gained by increasing the number of responses. Great care was exercised to note that each test item was tallied in the category in each classification of the outline so that a proper distribution of items according to the predetermined proportions was maintained.

An attempt was made to arrange the questions in the order of their scientific difficulty. This order was based upon the subjective evaluation of the writer.

In order that the student may not be able to select the correct response simply because it contains the word "friction", this word is used in the incorrect answers to the following questions: 116, 126, 130, 139, 141, 155, 161, 165, 191, 207, 208, 211, and 270. In 47 cases, the correct answer is the shortest answer, and in 49 cases it is the longest answer. Answer A is correct 72 times, B is correct 79 times, C is correct 72 times, and answer D is correct 77 times. Knowledge of friction is tested in its application to life situations rather than in the recall of formal laws. This is illustrated in the application of the laws of friction to skating, ashes, nails, sand, cloth, matches, shoes, and rubbers. Most children are interested in the automobile and its method of operation.[1] 24 different questions in this test deal with the automobile.

Since the twenty-eight key texts were written mainly for pupils on grade levels X, XI, XII, it was decided to make a rather complete study of the vocabularies used in these texts. Observations made by the writer during thirty-two years of teaching experience have convinced him that many students fail on certain topics because they do not understand the meaning of words commonly employed in textbooks which they study.

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1. See page 121.

A vocabulary of the words found in the twenty-eight texts was constructed. These words were then rated for range and frequency on the Thorndike[1] list. This vocabulary was used in constructing the test. The difficulty rating referred to in the next few pages is that determined by Dr. Thorndike[2] in his 20,000 word book.

Every effort possible was made to reduce the word difficulty throughout the first one hundred fifty questions. The common technical language of the subject was used after question two hundred was reached.

Some conception of the method of reducing word difficulty may be acquired from the following illustrations :

Original phrase	Rating	Simpler phrase	Rating
Sidewise	18	To one side	1
Velocity	9	Speed	2
Irregularity	14	Rough surface	2
Projection	8	Ridge	3
Mainly	12	For the most part	1
Retard	11	Check	2
Accelerator	19	Gas	3
Gravity	7	Pull of earth	1

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[1] E. L. Thorndike, Teacher's Word Book of Twenty Thousand Words, Teachers College, Columbia University, New York, 1931.

[2] Ibid.

The test contains slightly more than ten thousand words. This is a grand total and does not mean that the test contains ten thousand different words.

The list below shows that most of the words in the test have a difficulty or range rating which is below 7.

Difficulty	Number of words
7	14
8	13
9	15
10	7
11	4
12	6
13	3
14	4
15	2
16	2
17	2
18	3
19	2
20	0
Over 20	14
Total	91

A limited rearrangement was next attempted based upon word difficulty. When this arrangement had been made, the result did not seem entirely satisfactory, however, because a simple and now quite common word like "ski", having a rating of 17, would place an otherwise very simple question among other questions requiring difficult reasoning processes.

A third arrangement was then attempted, based upon the frequency of the phenomena and the difficulty of the reasoning processes involved. In order that this arrangement might not become too subjective, the following word difficulty arrangement was strictly adhered to :

1. No word of difficulty greater than 6 in the first 50 questions.
2. No word of difficulty greater than 7 in the first 100 questions.
3. No word of difficulty greater than 8 in the first 125 questions.
4. No word of difficulty greater than 9 in the first 150 questions.
5. No difficult problems or abstract theory in the first 200 questions.

A set of directions for marking may be found on the second page of the test pamphlet. Two illustrative questions are included. A complete copy of the test is to be found on pages 5-52.

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

CHAPTER V

DESCRIPTION OF THE SURVEY

The test was divided into three sections or forms for the purpose of administration because it was thought that the element of fatigue, especially in the lower grades, would affect the accuracy of the results. Preliminary experimentation gave evidence of the fact that a period of 40 minutes was ample time for the marking of each form.

A complete set of directions for administering the test was placed in the hands of every teacher. A copy of the "Directions for Administering" may be found in Appendix A.

In order to compare country boys and girls with city boys and girls, the test was given in two country schools and two city schools. It was finally decided to make a chance selection of schools. A large number of letters were written to the school superintendents of many cities and towns. The first city and town south of Boston and the first city and town north of Boston which expressed their willingness to give the tests were selected.

The spring of 1939 was chosen as the most appropriate

time for making the survey. Schools are well organized at this time of year and programs are not yet disrupted by preparations for graduation and final examinations.

Grades VII, VIII, IX, X, XI, and XII were selected for the survey. The test was administered to 40 students on each of the above-mentioned grade levels in the four schools selected. Nearly 960 pupils took the test. About 900 completed papers resulted from this administration.

CHAPTER VI

ANALYSIS OF THE DATA

The scoring of the test involved the detailed checking of approximately one million eighty thousand possible answers. This required about two years of intensive work. A grade in per cent has now been sent to every student who took the test.

During the process of scoring, 72 large grade sheets were constructed. These grade sheets are 24 inches long, and show the number of correct answers, the number of incorrect answers, and the number of answers omitted by each student. There are three forms (A, B, and C) of grade sheets. Each form contains one hundred test questions. The scores for boys may be found on the upper half of each grade sheet and the scores for girls appear on the lower half. The analysis of data is, therefore, made on the basis of communities, grade levels, and sexes. An analysis by topics or concepts is made later in the investigation.

Each form score was corrected for guessing by the use of the formula (Score = Rights-Wrongs / (n-1)), where "n" is the number of responses presented.[1] After the scores were corrected for guessing, averages for each sex, each form, each grade, and each school were carefully calculated.

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1. G.M. Ruch and G.D.Stoddard, *Tests and Measurements in High School Instruction*, World Book Company, Yonkers-on-Hudson, New York, 1927, p.292.

The order of difficulty of the test items was determined from the test scores. This difficulty table was based upon the per cent of correct answers obtained for each question. A table was first prepared for the boys and then a similar table was prepared for the girls. These two tables were combined to secure the order of difficulty for all students. Copies of the above tables will be found in Appendix A.

The order of difficulty table shows that question No.2 was the easiest question and question NO.220 was the most difficult. Question No.1 was 47th in order of difficulty and question No.300 was 231 in order of difficulty. The ten easiest questions included three questions with numbers above one hundred. The first 100 questions arranged in order of difficulty contained eleven questions which were numbered above 200 in the test.

The separate tables for boys and girls were calculated for the purpose of testing the effect of sex on the minor concepts of the subject. It was thought that the boys might show a much greater superiority in regard to some of the topics. No topic could be found which exhibited this superiority as a whole. Individual questions, however, exhibited great variation.

This may be illustrated by questions 7, 9, 41, and 165. These questions deal with the concept of force. Question 9 was answered correctly by 79% of the girls and 58% of the boys who attempted it. Question 7 was answered correctly by 80% of the girls and only 74% of the boys. Question 41, however, was an-

swered correctly by 53% of the boys and only 30% of the girls. Question 165 was answered correctly by 22% of the boys and 14% of the girls.

The facts stated above may be summarized in the following table:

Question	Boys	Girls	Differences
7	58%	79%	21%
9	74%	80%	6%
41	53%	30%	22%
165	22%	14%	8%

Questions 7 and 165 deal with the measurement of force, question 9 is based on the nature of force, and question 41 tests the pupils' knowledge of the unit in which force is measured. Although the percentage difference is in favor of the boys, there is no conclusive evidence that they possess a distinctly superior knowledge of the concept as a whole.

The percentages of students who had correct answers for each question on each grade level were used to illustrate by graphic methods, the acquisition of the six major portions (A,B,C,D,E, and F) of the concept (consult Outline, pages 80-85), Section B,(Advantages and disadvantages of friction) was illustrated by two graphical representations or curves. Section C (How friction may be controlled) was also represented by two curves. Section F (Heat results from friction) was graphically presented by the drawing of four curves. The other main portions of the concept (Sections A, D, and E) were each represented by a single curve. The eleven curves were then combined to form a single graphic representation of the whole concept.

Table No. I : This table shows the per cent of correct answers, on each grade level, for each minor topic contained in Section A of the general outline. This section deals with the definition of friction, the definition of force, and the units used in measuring force. Section A 2 tests the students' knowledge of the fact that friction is mainly caused by irregularities in surface. In this and the following tables, one hundred fifty pupils were tested on each grade level. The wide variation of curves D and E may be due to inadequate sampling. Curve A is obtained from the averages shown at the foot of each of the six columns. Conclusions are drawn mainly from the figures in the table rather than from the curve.

TABLE I

% Correct Scores

Outline	No. of Question	VII	VIII	IX	X	XI	XII
A 1	8	39.1	46.6	52.4	60.7	58.6	61.5
A 1a	2	25.5	32.1	33.8	42.3	40.4	43.1
A 1a(1)	4	43.0	49.0	45.2	49.2	52.3	42.7
A 1a (2)	4	12.8	13.1	18.0	18.1	18.1	19.9
A 1a(2) (a)	2	21.2	23.4	30.5	24.4	27.5	26.5
A 1a(2) (b)	2	16.3	12.3	26.7	20.9	27.8	12.4
A 1a(3)	7	15.5	22.4	24.7	22.1	23.2	18.3
A 2	6	32.4	38.3	42.2	26.9	44.8	48.6
A 2a	2	19.0	20.6	29.9	30.6	35.4	45.9
Average		25.0	28.6	33.7	36.1	36.5	35.4

Conclusions: Pupils in Grade VII have little difficulty in mastering the concept of force, (A 1a). Knowledge of units used in measuring this force, especially in the absolute units (A 1a(2) (b)), may be acquired in Grade IX. A knowledge of the subject of adhesion (A2a) develops quite rapidly after Grade VIII has been passed. Curve A shows that a knowledge of the nature and cause of friction increases rapidly in Grades VII to IX. The curve becomes nearly flat in Grade XI and drops slightly in Grade XII.

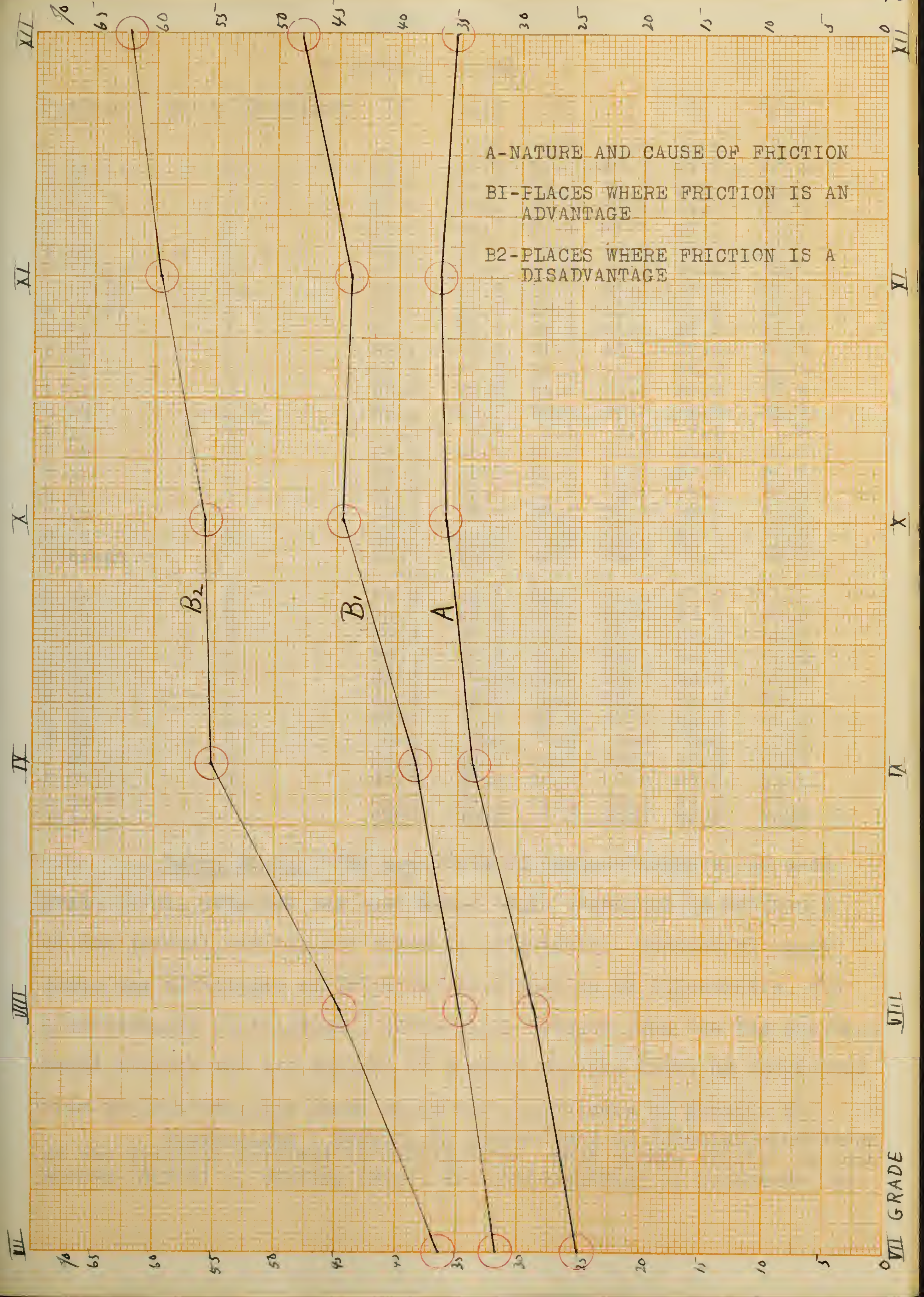

A-NATURE AND CAUSE OF FRICTION
B1-PLACES WHERE FRICTION IS AN ADVANTAGE
B2-PLACES WHERE FRICTION IS A DISADVANTAGE
A
B_1
B_2
GRADE
VII
VIII
IX
X
XI
XII
%
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70

TABLE II

% Correct Scores

Outline	No. of Questions	VII	VIII	IX	X	XI	XII
B 1	0	0.0	0.0	0.0	0.0	0.0	0.0
B 1a	3	35.5	45.2	48.1	49.7	47.5	50.4
B 1b	3	58.3	62.2	58.6	65.7	68.1	73.3
B 1c	3	27.8	32.5	34.8	34.8	34.7	41.4
B 1d	2	27.8	32.1	33.4	49.8	51.3	47.6
B 1e	2	20.0	25.5	30.8	37.2	39.1	44.5
B 1f(1)	2	47.5	51.4	63.8	63.3	64.3	70.6
B 1f(2)	1	46.3	46.3	55.7	56.6	61.0	59.0
B 1f(3)	1	29.3	29.3	28.1	40.0	41.9	41.7
B 1g	1	21.4	21.2	28.6	36.4	38.8	36.2
B 1h	1	25.2	25.2	31.4	52.1	32.6	34.2
B 1i	1	27.8	22.6	27.4	46.0	43.7	41.4
B 1j	2	23.2	23.2	26.8	35.5	29.8	26.9
B 1k	1	24.1	38.7	42.6	47.2	52.8	63.9
B 1l	1	7.2	7.5	6.5	8.2	7.4	7.5
B 1m	2	64.6	63.6	65.3	65.7	65.0	62.3
B 1n	1	28.6	28.8	30.2	27.6	34.3	34.9
B 1o	1	21.2	18.3	21.5	35.8	19.8	63.2
B 1p	1	23.7	28.8	37.3	32.8	33.6	34.2
B 1q	1	45.7	59.0	61.5	63.1	66.1	79.5
Average		31.9	34.8	38.5	44.6	43.8	48.0
B 2a	1	34.3	46.1	62.4	58.4	61.5	61.1
B 2b	2	19.4	22.8	35.4	32.6	29.4	41.9
B 2c	2	51.2	51.2	62.9	60.9	59.6	63.6
B 2d	2	24.6	37.7	41.9	53.0	54.1	53.3
B 2e	2	44.5	47.9	55.2	53.9	62.8	61.6
B 2f	1	45.3	65.8	76.3	75.8	81.5	90.0
B 2g	1	22.3	31.1	38.6	37.7	44.8	49.0
B 2h	0	0.0	0.0	0.0	0.0	0.0	0.0
B 2h(1)	1	26.2	46.5	63.1	57.1	65.3	68.8
B 2h(2)	1	47.6	47.6	58.8	65.2	67.0	62.1
B 2h(3)	1	49.1	49.5	58.4	63.6	69.6	69.9
Average		36.5	44.6	55.3	55.8	59.6	62.1

Table No.II: The per cents of correct answers, on each grade level, obtained for each minor topic contained in Section B of the general outline are given in this table. Section B1 represents the advantages of friction while Section B2 illustrates the disadvantages of friction. Curve B1 is derived from the six averages found beneath the six columns of Section B1, and Curve B2 is plotted from the six averages found below the six columns of Section B2.

Conclusions : Section B1 (Advantages of friction)-Knowledge of the friction involved in walking(B1b), wood screws (B1f(1)), jack screws (B1f(2)), skating (B1m), and grinding(B1g) is possessed in

very substantial amounts by pupils of Grade VII and Grade VIII. It is very interesting to note that the pupils of Grade VII are in possession of a concept of the friction involved in skating which is as advanced as that possessed by the students of Grade XII. It is also astonishing to note that a knowledge of the part played by friction in the striking of a match (B1l) is not understood by the students of Grade VII, and that this meager knowledge does not increase as the student advances to Grade XII.

Knowledge of the other applications of friction mentioned in the general outline is possessed in moderate amounts by the pupils of Grade VII and increases in a rather uniform ratio until Grade XII is reached.

Section B2 (Disadvantages of friction)- More than 40% of the pupils of Grades VII and VIII checked the correct answers to questions relating to concepts in skiing (B2c), machine bearings (B2e), drilling (B2f), jackscrews (B1f(2)), and steering worms (B2h3). The disadvantages of friction in sliding (B2b) were not clear to students of Grades VII and VIII. The score averaged about 26% in skating (B2a), moving objects (B2d), grinding (B2g), screws (B2h), and wood screws (B2h1). The percentage increase of this set of scores was gradual, as would be expected, until Grade XII was reached. The knowledge of drilling increased to a very high score (90%) in Grade XII.

The curve for B1 (Advantages of friction) rises very rapidly in Grade X, while the curve for B2 (Disadvantages of friction) rises very rapidly in Grade IX.

TABLE III

% CORRECT SCORES

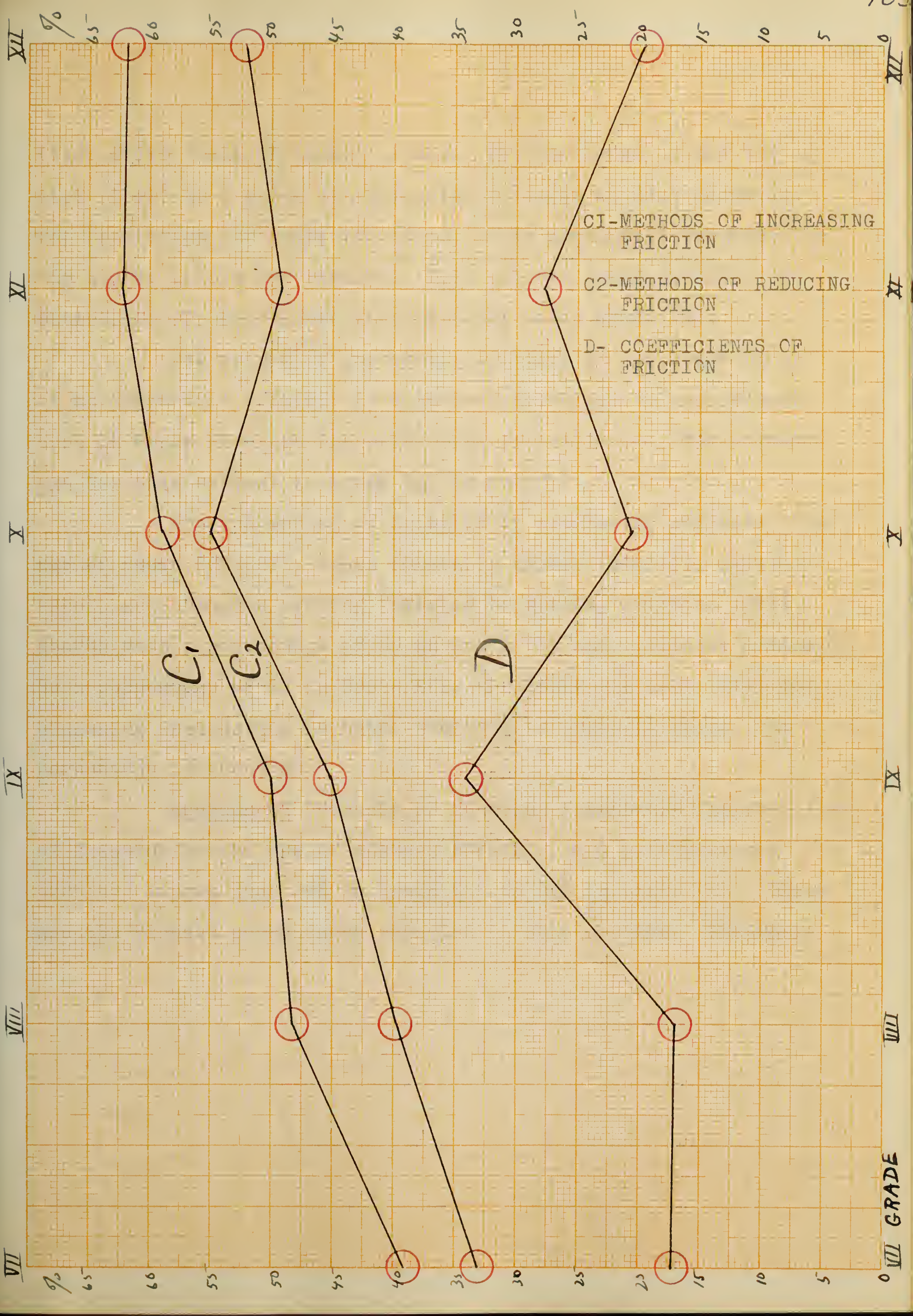
C

Outline	No. of Questions	VII	VIII	IX	X	XI	XII
C 1a	4	38.1	49.5	59.0	63.7	63.7	68.4
C 1a(1)	2	46.3	57.2	58.5	74.2	69.8	73.1
C 1a(2)	1	28.5	37.4	32.8	51.1	49.3	52.9
C 1a(3)	2	53.1	61.9	64.8	66.1	67.2	68.1
C 1a(4)	1	38.8	42.0	47.3	56.7	53.6	56.9
C 1a(5)	1	10.7	22.1	23.9	39.0	67.5	37.8
C 1a(6)	1	69.7	81.0	84.0	81.3	86.5	84.5
C 1b(1)	2	24.6	29.7	16.3	46.2	42.8	42.3
C 1b(2)	1	52.2	45.0	47.4	43.4	45.4	46.1
C 1c	2	29.8	47.5	53.8	56.6	61.7	68.8
C 1d	2	44.1	51.2	57.9	64.9	69.3	66.1
C 1e	2	36.1	54.8	53.9	65.3	71.7	77.4
		39.3	48.3	50.0	59.0	62.4	61.9
C 2a	2	37.8	47.1	57.2	63.6	61.3	65.5
C 2a(1)	0	0.0	0.0	0.0	0.0	0.0	0.0
C 2a(1)(a)	3	22.8	19.6	25.4	33.1	21.5	23.7
C 2a(1)(b)	1	20.1	26.5	44.5	52.1	57.6	53.2
C 2a(2)	10	37.6	44.1	50.4	54.4	54.9	57.7
C 2a(2)(a)	0	0.0	0.0	0.0	0.0	0.0	0.0
C 2a(2)(a)(1	1	43.5	44.2	37.9	39.7	35.2	36.2
C 2a(2)(a)(2	3	15.8	22.6	29.1	44.9	28.2	36.7
C 2a(2)(a)(3	2	29.9	27.6	33.9	35.6	39.4	33.3
C 2a(2)(a)(4	2	22.0	23.1	26.5	49.4	32.3	39.6
C 2a(2)(a)(5	2	15.9	13.2	19.3	61.2	13.5	10.6
C 2a(2)(b)	1	37.3	47.2	42.9	62.0	58.3	57.6
C 2a(2)(c)	1	25.3	36.1	27.6	40.6	34.5	37.1
C 2a(2)(d)	1	35.4	47.8	63.5	69.9	68.8	76.0
C 2a(2)(e)	1	36.5	57.3	65.3	73.1	75.2	76.0
C 2b	5	32.7	50.8	47.4	46.8	51.3	54.8
C 2b(1)	4	26.1	32.4	38.0	38.4	36.1	39.3
C 2b(2)	1	59.6	66.3	73.8	77.3	77.6	82.3
C 2b(3)	3	39.7	46.8	53.6	62.8	63.4	72.1
C 2b(4)	3	58.1	66.7	74.8	85.1	78.1	85.8
		33.1	40.0	45.1	55.0	49.3	52.1

Table No.III: This table gives the per cent of correct answers for each question, on each grade level, secured for every minor topic found in Section C (How friction may be controlled) of the general outline. Section C1 tests the student's knowledge of methods of increasing friction and Section C2 examines the knowledge the student possesses in regard to methods of reducing friction. Curve C1 is secured from the six averages found below the six columns of Section C1, and Curve C2 is derived from the six averages found below the six columns of Section C2.

Conclusions: Section C1 (Methods of increasing friction)- The method of increasing friction by use of automobile chains (C1a(6)) is understood by about 70 % of the students in Grade VII and increases gradually to nearly 87 % in Grade XI. There is a slight drop to about 85 % in Grade XII. This is, then, the proper starting point (i.e. Grade VII), for the teaching of methods of increasing friction.

Methods of increasing friction by the use of sand (C1a(1)), carpets (C1a(3)), lack of moisture (C1d) start with an average percentage of 48 in Grade VII and gradually increase to an average percentage of 62 in Grade XII. It is quite evident that these portions of the concept can be taught on all


CI-METHODS OF INCREASING FRICTION
C2-METHODS OF REDUCING FRICTION
D- COEFFICIENTS OF FRICTION
C_1
C_2
D
VII GRADE
VIII
IX
X
XI
XII
%
65
60
55
50
45
40
35
30
25
20
15
10
5
0

(i.e. above Grade VI) grade levels. The knowledge of the use of dirt (Clb2) as a means of increasing friction is most peculiar. The percentage for Grade VII is 52. This percentage decreases as the higher levels are reached. This subject could probably be satisfactorily approached on some level below Grade VII.

The method of increasing friction in the brake shoes of an automobile (Cla(5)) is a subject which can be approached best in Grade XI where the percentage is nearly 68. The percentage for this subject in Grade VII is only 11.

The increasing of friction by roughening surfaces (Cla), use of resin (Cla(2)), ashes (Cla(4)), rubber (Clb(1)), pressure (Clc), and changing rolling friction to sliding friction (Cle), starts with a percentage of 33 in Grade VII and increases gradually to a percentage of 61 in Grade XII. Probably the best level for beginning instruction in these subjects is Grade IX where the percentage is about 50.

Section C2 (Methods of reducing friction)- The reduction of friction by the use of casters (C2b(2)), and ball bearings (C2b(4)) ranges from 59% in Grade VII to 84% in Grade XII. These are the highest percentages recorded in this section. The whole

subject of fluid friction (C2a(2)(a)) (1 to (5)), which contains ten questions, ranges from a percentage of 26 in Grade VII to a percentage of 32 in Grade XII. This is a subject which, if taught at all, should be handled with extreme caution on any grade level.

The reduction of friction by the use of paraffin (C2a(3)(d) and soap (C2a(2)(e)) jumps from 36% in Grade VII to 64% in Grade IX. The average attained in Grade XII is 76%.

The part played by bearing metals in reducing friction (C2a(1)(a)) is represented by 23% in Grade VII and 24% in Grade XII. This gives evidence of the fact that the student does not greatly increase his knowledge of this important subject by contact with his environment during this period (Grade VII to Grade XII). This is an essential factor with which the teacher of physics should be familiar.

The other minor units in this topic, reducing friction by making surfaces smooth (C2a), watch jewels (C2a(1)(b), use of liquids (C2a(2)), cup grease (C2a(2)(b), graphite (C2a(2)(c)), changing sliding friction into rolling friction (C2b), wheels (C2b(1), and roller bearings (C2b(3)), increase normally from an average of 32 to an average percentage of 55.

Curve CI shows that knowledge of methods for increasing friction rises most rapidly in Grades VIII and X. Curve C2 indicates that knowledge of methods for reducing friction increases most rapidly in Grade X.

Table No. IV: A list of the per cent of correct answers, on each grade level, calculated for each minor topic contained in Section D(Coefficients of friction) of the general outline, may be found in this table. Curve D was plotted from the averages shown at the foot of each of the six columns.

TABLE IV

% CORRECT SCORES

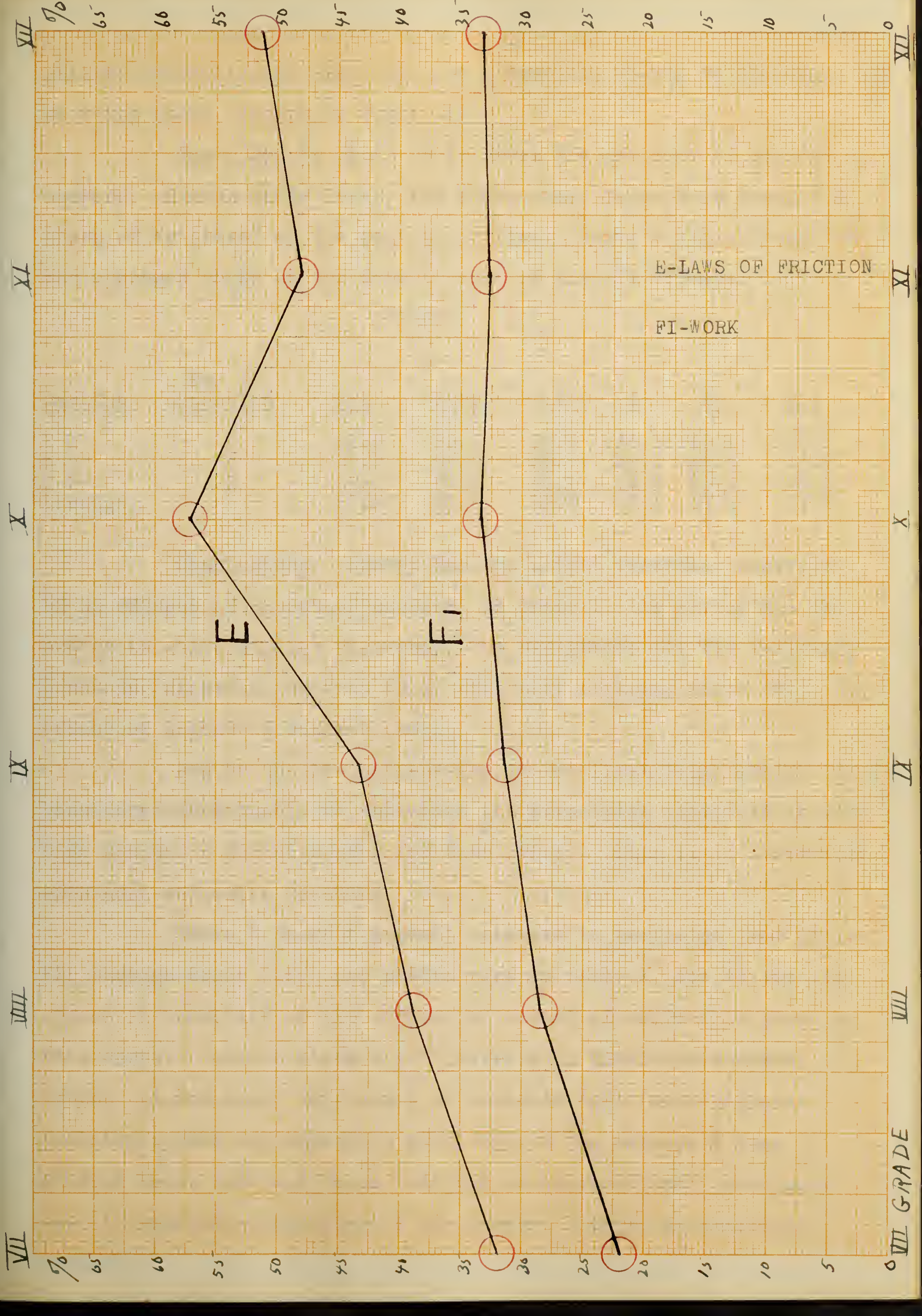
D

Outline	No. of Question	VII	VIII	IX	X	XI	XII
D	3	13.5	13.4	35.4	12.6	10.9	11.1
D 1	3	13.5	12.5	63.7	14.3	16.7	16.0
D 2	3	21.4	19.9	31.6	16.9	18.6	18.2
D 3	2	13.7	14.2	22.7	30.3	28.1	23.0
D 4s	2	22.3	20.3	32.6	30.8	33.9	30.0
D 4r	4	20.7	23.0	18.8	18.4	58.3	18.9
Average		17.5	17.2	34.1	20.6	27.8	19.5

Conclusions: The precentage for coefficients of sliding friction (D1) suddenly jumps from an average of about 14% on five grade levels to 64% in Grade IX. The percentage for coefficients of rolling friction (D4r) increases suddenly to 58% in Grade XI from an average percentage of 19 for the other five grades.

Since the general average for Grade XII (19.5) is only 2% above the general average for Grade VII (17.5), it is quite evident that, except for two unusual variations, the knowledge of the coefficients does not rise appreciably as the student advances to higher grades. This evidence tends to show that the study of this subject should be deferred until the higher grade levels are reached. It would be a serious mistake to begin the study of friction with a discussion of the coefficients.

Curve D shows graphically the fluctuations which take place in this minor topic. There is a sudden rise of the curve in Grade IX, a drop of considerable proportion in Grade X, a rise of


E-LAWS OF FRICTION
FI-WORK
E
FI
%
65
60
55
50
45
40
35
30
25
20
15
10
5
0
VII GRADE
VIII
IX
X
XI
XII

smaller proportion in Grade XI; and a descent, nearly to the Grade VII starting point, occurs in Grade XII.

Table No. V: This table gives the per cent of correct answers, on each grade level, for every minor concept in Section E (Laws of friction) of the general outline. Curve E was plotted from the averages shown at the foot of each of the six columns.

TABLE V

E

Outline	No. of Question	VII	VIII	IX	X	XI	XII
E 1	7	31.9	36.7	47.5	46.6	48.1	49.1
E 2	5	37.2	50.1	52.7	59.8	62.2	64.9
E 3	8	27.0	29.9	30.1	64.9	33.9	40.2
Average		32.0	38.9	43.4	57.1	48.1	51.4

Conclusions: Except for the slight irregular increase of E3 (Effect of extent of surface) in Grade X, the percentage increase is quite regular throughout the six grades for the following concepts: starting friction (E1), effect of pressing force (E2), and effect of extent of surface (E3).

Due to the low percentages in the first three grades, it is considered inadvisable to introduce the principles mentioned in Section E until a definite need for them arises. This is in accordance with good objective teaching.

Curve E shows a gradual increase in knowledge from Grade VII through Grade XII. The sudden rise in Grade X, due to the increase in knowledge of the effects of extent of surface is shown by this curve. Curve E shows a 19% increase in knowledge between Grades VII and XII. This seems to indicate that instructional techniques used for imparting knowledge of the Section E type, general laws, need not be as involved as instructional techniques used in imparting knowledge of the Section D type, mathematical concepts.

TABLE VI

% Correct Scores

Outline	No. of Questions	VII	VIII	IX	X	XI	XII
F 1a	5	29.6	50.7	48.3	53.4	54.1	55.4
F 1b	5	13.8	16.5	23.8	28.6	25.7	26.0
F 1c	6	31.8	33.8	36.0	29.6	33.5	28.7
F 1d(1)	11	16.5	18.7	21.6	26.3	25.1	30.7
F 1d(2)	3	18.1	22.8	28.0	29.5	25.4	25.7
Average		22.0	28.5	31.5	33.5	32.8	33.3
F 2a	7	28.9	36.9	46.3	53.1	57.0	61.2
F 2b	6	33.5	36.8	46.1	55.8	55.2	63.4
F 2c	5	15.7	15.9	20.7	20.6	19.1	28.6
F 2d	6	23.7	22.5	26.0	21.3	23.1	20.7
Average		25.5	28.0	34.8	37.7	38.6	43.5
F 3a	6	38.5	39.8	46.3	56.2	63.1	68.4
F 3b	6	29.3	25.4	31.1	43.9	42.7	50.1
F 3c(1)	3	24.1	24.3	25.9	14.1	28.8	21.9
F 3c(1) (a)	4	44.3	57.4	67.8	70.4	72.8	72.4
F 3c(1) (b)	3	25.8	29.3	49.2	42.6	62.1	68.1
F 3c(2)	3	21.6	22.5	23.3	25.1	33.2	27.3
F 3c(3)	3	19.6	20.9	32.3	34.4	38.8	45.0
F 3c(4)	5	15.2	15.9	15.2	18.5	26.1	17.0
F 3c(5)	6	23.2	22.4	23.2	25.3	30.6	22.0
F 3c(6)	4	15.5	14.6	15.5	17.2	15.8	9.9
Average		25.7	27.3	33.0	34.8	41.4	40.2
F 4a	5	27.5	31.4	46.5	49.7	51.5	53.3
F 4b	8	32.5	43.3	57.9	52.8	58.0	63.1
F 4c	3	13.5	19.9	15.5	14.7	14.0	11.2
F 4d	2	11.7	11.5	16.7	12.7	8.8	9.9
Average		21.3	26.5	34.2	32.5	33.1	34.4

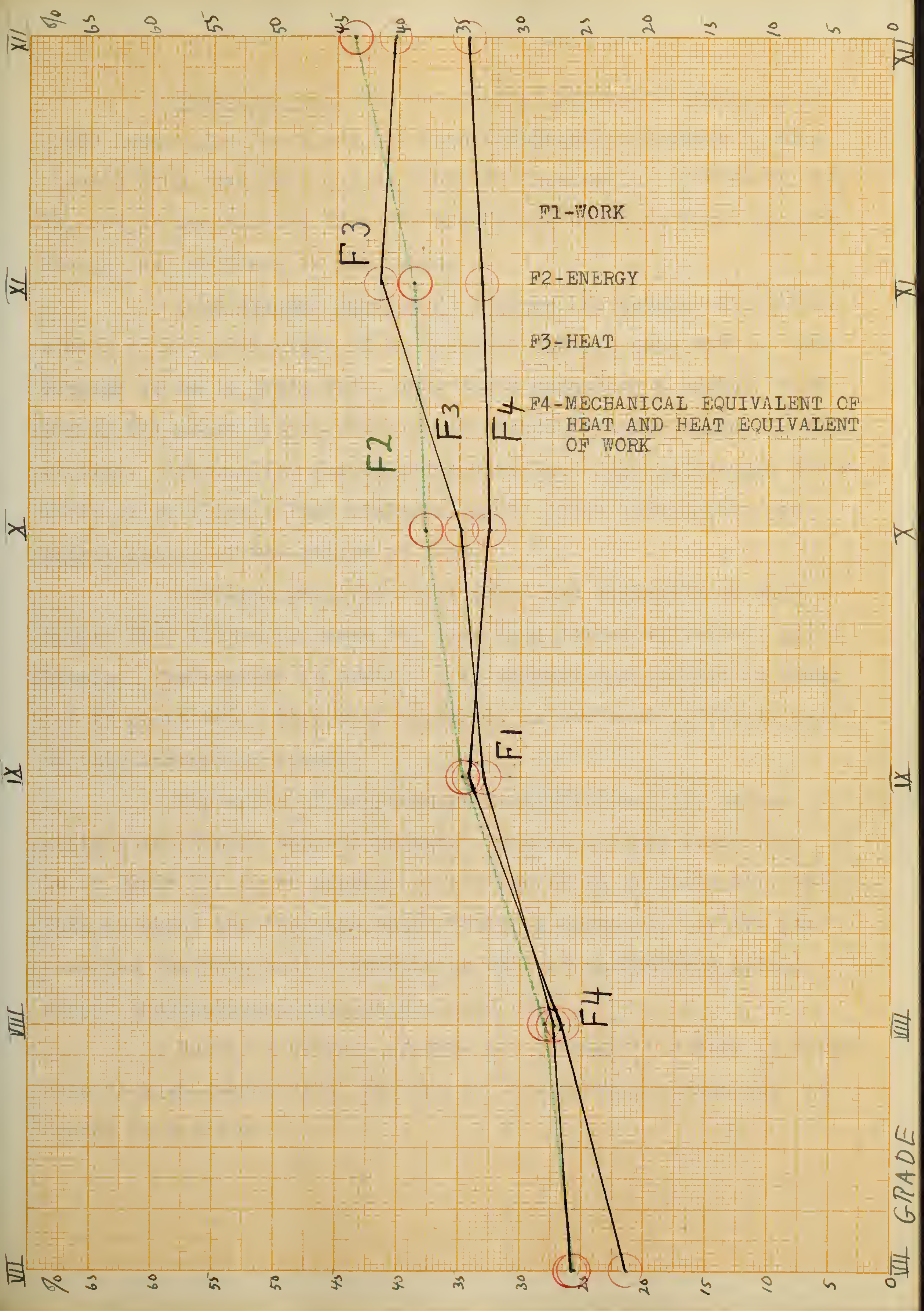

F1-WORK
F2-ENERGY
F3-HEAT
F4-MECHANICAL EQUIVALENT OF HEAT AND HEAT EQUIVALENT OF WORK
F1
F2
F3
F4
%
65
60
55
50
45
40
35
30
25
20
15
10
5
0
VII
VIII
IX
X
XI
XII
GRADE

Table No. VI: The per cent of correct answers, on each grade level, for the minor concepts contained in Section F (Heat results from friction) may be found in this table. Curves F1, F2, F3, and F4 are plotted from the six column averages found in each of the four sections of the table.

Conclusions: Section F1 (Work)- The nature of work(F1a) starts with a percentage of 30 in Grade VII and ends with a percentage of 55 in Grade XII. This topic maintains a higher standing on all grade levels than is maintained by other topics in this section. Instruction should begin with this high percentage topic. It is quite evident that students on all grade levels have some understanding of the nature of work.

Problems involving work (F1c) are evidently of such a nature that little progress has been made on the different grade levels. The average in Grade VII is 32% and the average in Grade XII is about 29%. This will evidently be the most difficult part of this concept to teach.

The units of measurement used (F1b) and the nature of efficiency (F1d(1) and (2) increase from an average percentage of 16 in Grade VII to an average percentage of 28 in Grade XII. While this is about the increase which would be expected, the low percentages indicate that difficulties will be encountered unless proper instructional methods are used.

Curve F1 shows a gradual and constant increase in knowledge through Grades VIII, IX, and X. The curve flattens out in Grades XI and XII.

Section F2 (Energy)- Knowledge of the nature (F2a) and kind of energy (F2b) increased quite uniformly from Grade VII (average 32%) to Grade XII (average 62%). It is quite evident that these subjects can be taught with profit on all grade levels. The case is quite different with units used in measuring energy (F2c) and problems involving energy (F2d). Knowledge of these concepts starts at 20% in Grade VII and increases to only 24% in Grade XII. These units should be taught only on the higher grade levels. Curve F2 shows the average characteristics of this group of four concepts. The flattening tendency of the last two concepts is somewhat concealed by the rapid rise of the first two.

Section F3 (Heat)- Knowledge of the nature of heat (F3a), molecules (F3b), Fahrenheit thermometer (F3c(1)(a)), Centigrade thermometer (F3c(1)(b)), and calorie (F3c(3)) increased from an average of 32% in Grade VII to 61% in Grade XII. These subjects can readily be taught on all grade levels. The starting point can be approximated from the percentages given.

Concepts of the British Thermal Unit F3c(2) and specific heat (F3c(4)) are quite meager. The average percentage for Grade VII is 19 and for Grade XII it is only 22. This difficulty is probably due in part to lack of opportunity to observe, in the case of the British Thermal Unit, and to the complexity of the concept, in the case of specific heat.

The student's knowledge of degrees of temperature F3c(1), heat problems (F3c(5)), and heat equations F3c (6) decreases from an average of 21% in Grade VII to 18% in Grade XII. A consideration of the causes of this unusual phenomenon might lead to a discussion as to the practicability of this type of information.

Curve F3 rises gradually in Grades VII to X. There is a comparatively sharp rise in Grade XI which is followed by a slight drop in Grade XII.

Section F4 (Mechanical equivalent of heat)- The facts that heat is changed into work (F4a) and that work is changed into heat (F4b) are already growing concepts when pupils are in Grade VII. The percentage for these concepts as shown by Table VI rises from an average of 31% in Grade VII to 58% in Grade XII. The evidence here presented tends to show that the teaching of these subjects can be started in Grade VII.

The numerical value of the equivalent (F4c) and problems involving the mechanical equivalent attain an average percentage of 13 in Grade VII. This percentage decreases to 11 in Grade XII. The decreasing percentage probably indicates a lack of observation on the part of the pupil, or, at least, a tendency to do little thinking about what he has observed. Since these portions of the concepts are not essential to everyday life, their study should be postponed until higher grade levels are reached.

Curve F4, which illustrates the growth of the four concepts just mentioned, rises quite rapidly in Grades VIII and IX. This curve then tends to flatten out in Grades XI and XII.

TABLE VII

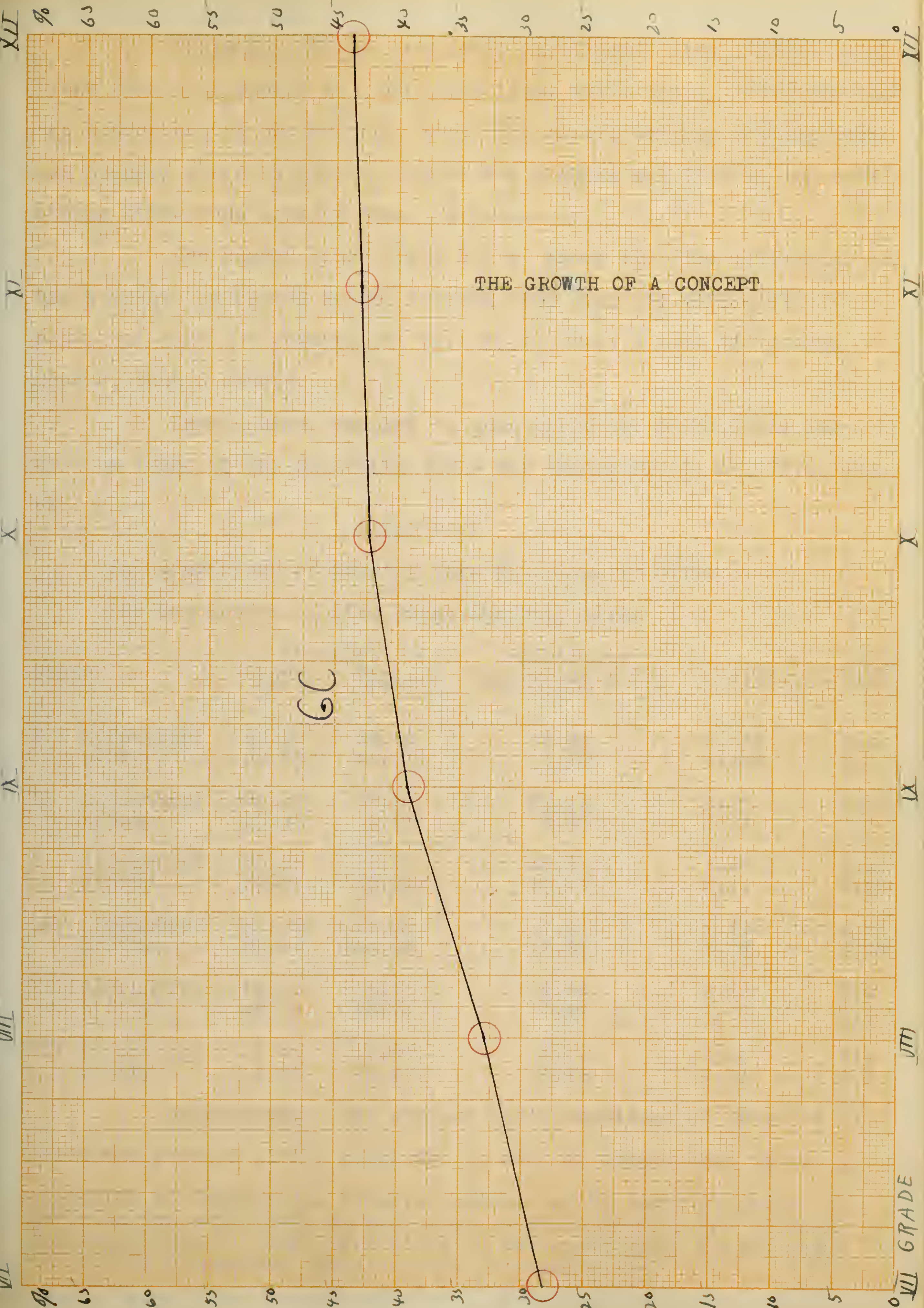
Final Average

% Increase in Scores

Outline	No. of Questions	VII	VIII	IX	X	XI	XII
A	37	25.0	28.6	33.7	36.1	36.5	35.4
B 1	30	31.9	34.8	38.5	44.6	43.8	48.0
B 2	14	36.5	44.8	55.3	55.8	59.6	62.1
C 1	21	39.3	48.3	50.0	59.0	62.4	61.9
C 2	46	33.1	40.0	45.1	55.0	49.3	52.1
D	17	17.5	17.2	34.1	20.6	27.8	19.5
E	20	32.0	38.9	43.4	57.1	48.1	51.4
F 1	30	22.0	28.5	31.5	33.5	32.8	33.3
F 2	24	25.5	28.0	34.8	37.7	38.6	43.5
F 3	43	25.7	27.3	33.0	34.8	41.4	40.2
F 4	18	21.3	26.5	34.2	32.5	33.1	34.4
Total	300	28.2	33.0	39.4	42.4	43.0	43.8

Table No. VII: The per cent of correct answers, on each grade level, for the eleven minor concepts into which the major concept is divided is shown in this table. Curve GC is plotted from the averages shown beneath the last six columns in the table.

Conclusions: The increases in learning on the several grade levels are as follows: from Grade VII to Grade VIII, 4.8% ; from Grade VIII to IX, 6.4% ; from Grade IX to Grade X, 3.0%; from Grade X to XI, 0.6%; from Grade XI to Grade XII, 0.8%.



THE GROWTH OF A CONCEPT

Table No. VIII: This table is obtained from statistical data in Appendix A. The first line, Grade XII A, indicates that the difference in the average, corrected scores between country boys and country girls is 15.24 and that the chances are 99.9 in 100 that a true difference greater than 0 exists.

The second line, Grade XII B, shows that the difference in the average, corrected scores between city boys and city girls is 6.88, and that the chances are 99.4 in 100 that a true difference greater than 0 exists.

Information, similar to that given above for Grade XII, will be found in the following table for Grades XI, X, IX, VIII, and VII.

TABLE VIII

(A) Comparison of Country Boys with Country Girls

(B) Comparison of City Boys with City Girls

Grade	Averages Boys	Averages Girls	Difference in Averages (D)	σ diff.	$\frac{D}{\sigma \text{ diff.}}$
XII A(Country)	40.90	25.66	15.24	3.344	4.5
B(City)	32.90	26.02	6.88	2.808	2.5
XI A(Country)	38.50	25.81	12.69	3.20	3.99
B(City)	13.62	8.77	4.85	2.82	1.7
X A(Country)	35.25	18.38	16.87	2.58	6.54
B(City)	33.01	19.54	13.47	2.97	4.54
IX A(Country)	25.73	18.39	7.34	2.29	3.21
B(City)	26.94	14.13	12.81	2.38	5.38
VIIIA(Country)	12.12	9.56	2.56	2.53	1.01
B(City)	28.18	23.91	4.27	2.78	1.5
VII A(Country)	16.63	11.50	5.13	2.16	2.4
B(City)	19.73	15.47	4.26	2.19	2.1

Conclusions: The average boy's knowledge of friction exceeds the average girl's knowledge to such an extent that it is a violation of fundamental teaching principles to teach friction to girls on the same level as that used in teaching friction to boys. The superiority of boys over girls on the upper grade levels seems to be most pronounced among country boys and girls.

TABLE IX

(A) Comparison of Country Boys with City Boys
(B) Comparison of Country Girls with City Girls

Grade		Averages City	Averages Country	Difference in Averages(D)	σdiff.	$\frac{D}{\sigma \text{diff.}}$
XII	A(Boys)	32.90	40.90	8.00	3.68	2.17
	B(Girls)	26.02	25.66	0.36	2.98	0.12
XI	A(Boys)	29.95	38.50	8.55	3.28	2.6
	B(Girls)	17.06	25.81	8.75	2.82	3.1
X	A(Boys)	33.01	35.25	2.24	3.05	0.73
	B(Girls)	19.54	18.36	0.16	2.48	0.06
IX	A(Boys)	26.94	25.73	1.21	2.98	0.41
	B(Girls)	14.13	18.39	4.26	1.41	3.02
VIII	A(Boys)	28.18	24.45	3.73	2.84	1.3
	B(Girls)	23.91	18.18	5.74	2.46	2.3
VII	A(Boys)	19.73	16.63	3.10	2.54	1.2
	B(Girls)	15.47	11.50	3.97	1.73	1.8

Conclusions: The evidence that country children are superior to city children in regard to knowledge of friction is not conclusive. Country boys in Grades X,XI, and XII seem to be somewhat superior to city boys. City boys in Grades VII, VIII, and IX score somewhat higher than country boys. No general conclusions in regard to superiority can be drawn in regard to country girls and city girls. There is some evidence, however, which seems to indicate that city girls in Grades VII and VIII are slightly superior, as far as knowledge of friction is concerned, to country girls.

Table No.X: This table shows the average, corrected scores of Grade XII boys and girls in four different schools. It also shows the number of Grade XII pupils tested in each school. Table No.XI gives the number of boys and girls in Grade IX of each school who equalled or exceeded the Grade XII scores made in their own school.

TABLE X

XII Grade Average

Corrected Scores

	Boys	No. of Boys tested	Girls	No. of Girls tested
School No.1	38.93	16	20.90	18
School No.2	33.80	16	24.66	15
School No.3	34.92	22	28.88	18
School No.4	25.50	16	20.48	20

TABLE XI

IX Grade Individual Scores which exceed XII Grade average scores

School No.1	43.63 40.67 49.89 51.78	20	25.44 24.56 26.78 22.55 22.33 21.33	24
School No.2	45.00 36.56	20	37.00 25.33 36.22	22
School No.3	45.00 36.56 40.56 60.22 42.78	18	33.11 39.44 33.27	7
School No.4	28.33 32.78 30.67 42.33 34.67 27.78 26.44 27.00 46.78	17	22.78 23.67	20

Conclusions: In School No.1, 4 boys and 6 girls equalled or exceeded the average score of Grade XII. In School No. 2, 2 boys and 3 girls equalled or exceeded the average score of Grade XII. In School No.3, 5 boys and 3 girls equalled or exceeded the average score of Grade XII. In School No. 4, 9 boys and 2 girls equalled or exceeded the average score of Grade XII.

It is true, with respect to knowledge of friction, that some 9th graders know as much as the average 12th graders.

Table NO. XII: This table gives the average, corrected score made by each grade in each school. Average, corrected scores made by all schools on each grade level are also given. The per cent increase in knowledge of friction made on each grade level is calculated. Conclusions are drawn from the percentage variations.

TABLE XII

Form A and B only
Both Boys and Girls
Average Scores(corrected)

Grade	VII	VIII	IX	X	XI	XII
School No.1	17.83	23.21	32.61	33.54	37.12	40.32
School No.2	13.87	17.10	26.93	39.35	43.80	39.14
School No.3	20.32	29.92	29.41	41.89	31.72	41.01
School No.4	12.30	21.44	26.98	30.66	29.50	31.81
Average	16.08	22.92	28.98	36.36	35.54	38.07

Total increase in scores 38.07--16.08 21.99

Per cent of total increase in knowledge of friction per grade from average scores:

Grade VII to VIII	6.84 increase	31.1% increase
Grade VIII to IX	6.06 increase	27.5% increase
Grade IX to X	7.38 increase	33.6% increase
Grade X to XI	.82 decrease	3.7% decrease
Grade XI to XII	2.53 increase	11.5% increase
Total	21.99	100%

Conclusions: There is no sharply defined period where scientific interest in friction and resulting scientific observation is accentuated but there seems to be a decrease in interest and observation between grades X and XI in large city schools.

Table No.XIII: The table given here shows the number of first selections or choices made by pupils of Grades VII,VIII,IX,X, XI, and XII.

Table XIII

Choice of Subjects by All Pupils in All Schools

Boys							Girls					
VII	VIII	IX	X	XI	XII	SUBJECT	VII	VIII	IX	X	XI	XII
12	9	8	7	9	11	Radio	20	16	12	6	7	4
13	15	14	16	8	9	Auto	4	1	3	4	3	4
20	31	22	15	22	17	Airplane	8	15	4	13	1	3
9	6	7	9	8	9	Camera	22	25	23	25	15	10

Conclusions: The airplane was the subject of major interest to boys. With the exception of a slight change in Grade X from the airplane to the automobile, the interests of boys remained nearly constant in all grade levels.

The automobile was the subject of second choice for most boys. Table XIII indicates a slight change of this minor interest in Grades XI and XII. The interest change was from the automobile to the radio.

The camera was the subject of major interest to girls. This interest predominates,with little change,on all grade levels.

The radio was the subject of minor interest to girls. This minor interest undergoes a slight shift from the radio to the airplane in Grade X.

Tables No.XIV and XV: These tables list by schools the applications of science in which children on grade levels VII, VIII, IX, X, XI, and XII are interested. Table XIV is for boys and Table XV is for girls.

TABLE XIV

Choice of Subjects

Boys

	School No.1	School No.2	School No.3	School No.4		
Choice	Country	Country	City	City	Total	Percent
Radio	15	11	18	12	56	14.6
Auto	20	19	11	25	75	19.6
Airplane	31	22	34	32	119	31.1
Camera	9	5	25	9	48	12.5
Guns		1			1	.3
Engines	15	13	5	12	45	11.7
Mimeograph						0.0
Chemistry	3		3	1	7	1.8
Carpenter		1		1	11	.3
Nursing						0.0
Trains		1			1	.3
Television	1		1		2	.5
Telescope		1			1	.3
Telephone			1		1	.3
Boats		5	1		6	1.6
Dentistry						0.0
Typewriter				1	1	.3
Machine	1			1	2	.5
Music						0.0
Dressmaking						0.0
Biology						0.0
Cooking						0.0
Sewing						0.0
Bicycle				1	1	.3
Dancing						0.0
Printing			3	2	5	1.3
Electricity			5	1	6	1.6
Surveying		1	1		2	.5
Optometry			1		1	.3
Zoology			1		1	.3
X-Ray						0.0
Telegraph		1			1	.3
Total	95	81	110	97	383	

TABLE XV

Choice of Subjects

Girls

Choice	School No.1 Country	School No.2 Country	School No.3 City	School No.4 City	Total	Percent
Radio	15	19	15	16	65	21.6
Auto	6	2	4	7	19	6.3
Airplane	13	4	15	12	44	14.6
Camera	25	30	33	32	120	39.9
Guns						.0
Engines						.0
Mimeograph		1			1	.3
Chemistry	2		1		3	1.0
Carpenter						.0
Nursing	1			1	2	.7
Trains						.0
Television	1	1			2	.7
Telescope						.0
Telephone	1				1	.3
Boats			2	2	4	1.3
Dentistry	1				1	.3
Typewriter			2	4	6	2.0
Machine				9	9	3.0
Music			1	9	10	3.3
Dressmaking	1				1	.3
Biology		1		1	2	.7
Cooking	2				2	.7
Sewing	1				1	.3
Bicycle		1		4	5	1.7
Dancing		1		2	2	.7
Printing						.0
Electricity						.0
Surveying						.0
Optometry						.0
Zoology						.0
X-Ray			1		1	.3
Telegraph						.0
Total	69	59	74	99	301	

These forms were answered only by those students who had definite interests in the field of science.

Conclusions: 31.1% of the boys chose the airplane, 19.6% decided on the automobile, and 12.5% preferred the camera.

39.9% of the girls chose the camera, 21.6% preferred the radio, 14.6% liked the airplane, and 6.3% selected the automobile.

The major interests of country boys are practically the same as the major interests of city boys and the main interests of country girls are about the same as the main interests of city girls.

The correlation between the odd and the even questions of the test was found to be .97 . The reliability of the examination was found by substitution in Spearman's formula[1],

$$Rx = \frac{2rn}{1 + rn}$$

and by computation was found to be .98. The index of reliability[2] was .99. (See Appendix A).

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[1] Henry E. Garrett, Statistics in Psychology and Education, Longmans, Green and Company, New York, 1926, p.271.

[2] Ibid., p.273.

CHAPTER VII

SUMMARY AND CONCLUSIONS

1. The pupils of Grade VII have already acquired a knowledge of the meaning of the word force, but they have little knowledge of the units used in measuring this force. Knowledge of adhesion develops after Grade VIII has been passed. Knowledge of the nature and cause of friction increases rapidly to Grade IX. Little is added after this grade has been passed.

2. A knowledge of the advantages of friction increases very rapidly in Grade X, while a knowledge of the disadvantages of friction rises very rapidly in Grade IX.

3. Some of the methods for increasing friction are clearly understood by the students of Grade VII. Other methods are not comprehended until the higher grade levels are reached. The reduction of friction by the use of casters and ball bearings is fairly well known on all six grade levels, but the action of fluids and bearing metals is not well understood in any of the grades. Knowledge of methods for increasing friction rises most rapidly in Grades VIII and X while knowledge of methods for reducing friction increases most rapidly in Grade X.

4. Knowledge of the coefficients of friction is gained in Grade IX. Little knowledge of this subject seems to be gained after this grade has been passed.

5. Knowledge of the laws of friction increases most rapidly in Grade X. Although there is a decrease in knowledge of friction in Grade XI, the tendency otherwise is upward.

6. The relation of friction to work, energy, and heat, is a concept which may be gradually mastered through all grades. Knowledge of the relation between heat and energy may be gained most readily in Grades IX and XII, but the relationship between friction and heat is most readily acquired in Grade XI. Knowledge of the mechanical equivalent is learned most readily in Grade IX.

7. This investigation tends to show that learning, as judged by the knowledge of friction, takes place most rapidly in Grade VIII. It takes place at a lower rate in Grade XI than in any of the other grades under investigation.

8. The average boy's knowledge of friction greatly exceeds the average girl's knowledge.

9. The fact that country children are superior to city children as regards knowledge of friction, is not substantiated by the evidence presented in this investigation.

10. It is true, with respect to knowledge of friction, that some of the 9th graders know as much as the average 12th graders.

11. There is no period in the development of the child where scientific observation is accentuated as judged by the knowledge of friction.

12. There seems to be a decrease in interest in friction and resulting scientific observation in Grade XI. This is especially true in large city schools.

13. As a rule, the chief scientific interests of children remain constant from Grade VI through Grade XII.

14. The airplane represents the chief scientific interest of boys, and the camera is the primary interest of girls.

15. The major interests of country boys are practically the same as the major interests of city boys, and the main interests of country girls are about the same as the main interests of city girls.

16. Although the boys' knowledge of friction greatly exceeded that of the girls, no single topic could be found which exhibited this superiority as a whole.

17. The complexity of experiences, as judged by the knowledge of friction, was less on the lower grade levels than it was on the higher grade levels.

CHAPTER VIII

EDUCATIONAL IMPLICATIONS, OBSERVATIONS, AND AREAS FOR FURTHER RESEARCH

The establishment of definite knowledge levels for each grade places the teaching of friction on a more scientific basis. This does not mean that a pretest should not be given, but it gives the teacher a very definite concept regarding the matter which should be included in a pretest.

Knowledge of grade level topics enables the teacher to plan his course so that he will not attempt to give instruction in fields which can best be approached on some other level. If an instructor is without teaching experience on various levels, he has little concept of the instructional material he should present to the particular grade in which he finds himself teaching.

The students in Grade VII possess a knowledge of the friction involved in skating which is equal to that possessed by the pupils of Grade XII. On what grade level was this information gained ? The occurrence of several concepts of this nature seems to indicate that this investigation could profitably be extended to the lower grade levels. These objective data support Haupt's[1] statement that there is no experimental evidence which tends to show that content from the biological sciences is less difficult for children than content from the physical sciences and therefore better adapted to the lower grade levels of the elementary school.

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[1] G.W.Haupt, A Philosophy of Science Teaching in an Elementary School, Teachers College Contributions to Education, Number 633, Teachers College, Columbia University, New York, 1935, p.103.

Many failures in science are probably due to the fact that instruction does not begin on the proper level. Because of lack of understanding at the start, students often develop an aversion for a subject before they have a chance to learn its possibilities. This unnecessary antipathy is very difficult to overcome and may fundamentally change the life work of the student.

Before scientific teaching in a given field can really be developed, all transcendents must be studied and grade levels established. Until this has been done, teachers will continue their attempts to put square pegs into round holes. This study is an attempt to establish grade levels for a single major concept only.

The curve which illustrates the growth of the concept of friction rises rapidly in Grades VIII and IX. This same curve tends to flatten out in Grades XI and XII. It would be interesting to learn how skillful teaching of the subject of friction would affect the gradient of this curve on all grade levels.

This investigation presents substantial evidence that the average boy's knowledge of friction exceeds that of the average girl. If investigations, which may be subsequently conducted, give evidence of the fact that this is true regarding other major concepts of the subject, we are reasonably safe in assuming that the inception of instruction of both boys and girls on the same level is one of the causes which has practically eliminated the subject of physics as an elective for girls. Zim[1] states that the present

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[1] Herbert S. Zim, "Student Interest in Science", School Science and Mathematics, XLI, Number 4 (April, 1941), p.388.

educational treatment is such that sex differences become exaggerated and girls soon exclude themselves from several areas of science activity.

Since this investigation seems to indicate that country children are not greatly superior to city children as judged by their knowledge of friction, the teaching of this subject to country children should be on the same level as that used in teaching friction to city children.

Since the airplane represents the chief interest of boys, and girls are primarily interested in the camera, teaching, if it is to be objective, should begin with these major interests.

Certain minor concepts which remain constant or give evidence of no uniform increase in knowledge on the higher grade levels, are probably of little importance. While this static condition may be due in part to lack of observation, it is probably safe to assume that the student has but little use for information of this type. It is a serious mistake to include these topics in courses given to non-college students. Heat equations and problems involving the mechanical equivalent of heat are topics of this type.

APPENDIX A

LIST OF TEXTBOOKS

NUMBER	TITLE	AUTHOR	PUBLISHER	DATE OF PUBLICATION
1	Physics of Today	F.W.Sears J. Clark F. Gorton	Houghton Mifflin	1938
2	Practical Physics	N.H.Black H.N.Davis	The MacMillan Co.	1938
3.	First Principles of Physics	R.Fuller R.Brownlee D.Baker	Allyn and Bacon	1937
4	Unified Physics	G.Fletcher F.Mosbacher S.Lehman	McGraw and Hill	1936
5	Science in the World of Work	F.Deming J.Nerden H.Hall	McGraw and Hill	1936
6	Modern Physics	C.E.Dull	Henry Holt and Co.	1929
7	Household Physics	A.M.Butler	M.Barrows Co.	1929
8	Our Physical World	C.F.Eckels C.B.Shaver B.W.Howard	B.H.Sanborn	1938
9	Descriptive Physics	S.R.Wilson	Henry Holt and Co.	1936
10	Physics for Secondary Schools	O.Stewart B.Cushing	Ginn and Co.	1932
11	Practical Physics	Henry S.Carhart Horatio N.Chute	Allyn and Bacon	1927
12	Everyday Physics	C.J.Lynde	The MacMillan Co.	1930

NUMBER	TITLE	AUTHOR	PUBLISHER	DATE OF PUBLICATION
13	Physics in Everyday Life	W.D.Henderson	Lyons and Carmahan	1930
14	Physics Review	A.H.Killen	Oxford Book Co.	1928
15	Essentials of Physics	F.E.Sears	Laurel Book Co.	1931
16	High School Physics	F.R.Gorton	D.Appleton Co.	1910
17	Elements of Physics	R.Millikan W.Pyle H.Gale	Ginn and Co.	1927
18	School Physics	E.M.Avery	Sheldon and Co.	1895
19	Experiments in Physics	N.Henry Black	The MacMillan Co.	1923
20	Textbook of Physics	E.H.Hall J.Y.Bergin	Henry Holt and Co.	1897
21	Elements of Physics	H.Crew F.T.Jones	The MacMillan Co.	1909
22	Textbook of Physics	G.A.Wentworth G.A.Hill	Ginn and Co.	1898
23	Physics	C.R.Mann G.R.Twiss	Scott,Foresman Co.	1910
24	General Physics	C.S.Hastings	Ginn and Co.	1900
25	Elements of Physics	F.E.Merchant C.A.Chant	Henry Holt and Co.	1924
26	Elements of Physics	E.H.Hall	Henry Holt and Co.	1912
27	Outlines of Physics	E.L.Nichols	The MacMillan Co.	1897
28	Essentials of Physics	G.A.Hoadly	American Book Co.	1913

Directions for Administering

Read to students

I am going to give each of you a test booklet. Please do not open the booklet until you are told to do so.

Distribute booklets (See that each student has a booklet.)

Read to students

Fill in the blanks on the front of the booklet. (Allow 2 minutes) Place a check mark after the grade in which you now are. If you are a senior, check "Grade XII". If you are a junior, check "Grade XI", etc.

Read to students

Open the booklet and watch me as I fold over page one. Fold your booklet the same way and place it on the desk so that only page 2 is before you.

Read to students

Look at the directions while I read them.

"Put an X, in the brackets, before the most nearly correct completion word, statement, or answer. Use only one X for each numbered question. Do not write anything or mark the test in any other way.

Example Number 1

A circle is

( ) square.
(X) round
( ) rectangular
( ) longer than it is wide."

Read to students

Notice the X in the second pair of brackets. Since a circle is not square, rectangular, or longer than it is wide, we put an X in the brackets before the word "round", which is the best completion word for the sentence. Take your pencil and trace over the X so that your X is in the brackets before the word "round". (See that the pupils do this).

Read to students

Now let us look at

"Example Number 2

If a sidewalk is covered with one of the following substances, on which material would you be most likely to slip ?

( ) Sand.
( ) Ashes.
( ) Dirt.
(X) Ice."

Read to students

This time the X is in the bottom set of brackets. Since we are not likely to slip on sand, ashes, or dirt, we put the X in the brackets before the word "ice" because this is the substance on which we are most likely to slip. The word "ice" is the best answer.

Take your pencil and trace over the X so that your X will be in the brackets before the word "ice". (See that the pupils do this.)

Read to students

"Go through the booklet and answer first the questions which you can answer most easily. Then go back and try to answer as many of the other questions as you can. Keep working until you are told to stop. WORK RAPIDLY."

Read to students

The questions in the booklet are like these samples. Except that, of course, you will find no printed crosses to show you where to put your crosses. You will not be able to answer all the questions correctly. Do the best you can. Is there any question about what you are supposed to do ?

Answer any questions needed to make the instructions clear. When there are no more questions

Read to students

Turn over the test booklets and begin.

****

Record the time at which the students begin work. At the end of 20 minutes

Read to students

You have 20 minutes left in which to finish the test.

At the end of 20 more minutes (total time exactly 40 minutes) say, "STOP".

Collect the booklets

****

I have carefully followed all directions given on both direction sheets which accompany this test.

Signed______________________________________
Teacher in charge

Signed______________________________________
Teacher in charge

TABLE XVI

Grade XII

Corrected Scores

Country

	Boys	Girls
	Rockport & Hanover	Rockport & Hanover
1.	26.45	31.33
2.	44.89	9.78
3.	57.33	42.11
4.	71.33	64.00
5.	33.00	7.22
6.	45.11	7.67
7.	25.67	20.78
8.	28.44	13.22
9.	27.22	20.78
10.	76.11	20.66
11.	49.00	22.33
12.	40.12	31.67
13.	32.00	35.78
14.	24.44	41.55
15.	34.11	11.33
16.	44.67	29.22
17.	47.33	35.57
18.	49.78	9.45
19.	46.89	21.11
20.	28.78	14.56
21.	42.67	13.44
22.	63.68	26.22
23.	39.78	16.33
24.	26.66	16.89
25.	40.22	34.55
26.	33.33	7.22
27.	33.11	25.78
28.	29.89	28.78
29.	40.22	26.78
30.	41.22	21.67
31.		48.45

Range=76.33-24.44 = 51.89

Range=64.00- 7.22 = 56.78

TABLE XVII

Grade XII

Corrected Scores

City

	Boys Brookline & Medford	Girls Brookline & Medford
1.	29.89	27.78
2.	41.11	37.45
3.	25.44	22.56
4.	31.66	27.89
5.	43.78	9.22
6.	40.33	29.22
7.	9.78	32.56
8.	10.78	25.44
9.	47.67	38.44
10.	35.67	30.89
11.	51.67	42.33
12.	38.55	18.55
13.	39.89	37.00
14.	45.33	23.67
15.	45.44	21.00
16.	24.78	30.89
17.	43.00	39.22
18.	21.56	25.33
19,	31.22	10.00
20.	32.33	23.11
21.	38.89	10.22
22.	42.78	20.67
23.	15.89	37.11
24.	38.22	34.22
25.	23.78	18.33
26.	19.33	
27.	13.22	
28.	48.89	
29.	32.46	
30.	25.89	

Range = 51.67- 9.78 = 41.89

Range = 42.33-9.22 = 33.11

TABLE XVIII

Grade XII

Corrected Scores

Boys, Girls, City, & Country

Scores	Midpoint	F	D	FD		FD^2
76-78	77.5	1	15	15		225
73-76	74.5	0	14	0		0
70-72	71.5	1	13	13		169
67-69	68.5	0	12	0		0
64-66	65.5	1	11	11		121
61-63	62.5	1	10	10		100
58-60	59.5	0	9	0		0
55-57	56.5	1	8	8		64
52-54	53.5	0	7	0		0
49-51	50.5	3	6	18		108
46-48	47.5	5	5	25		125
43-45	44.5	7	4	28		112
40-42	41.5	11	3	33		99
37-39	38.5	10	2	20		40
34-36	35.5	6	1	6	(+187)	6
31-33	32.5	11				
28-30	29.5	9	-1	-9		9
25-27	26.5	13	-2	-26		52
22-24	23.5	7	-3	-21		63
19-21	20.5	9	-4	-36		144
16-18	17.5	4	-5	-20		100
13-15	14.5	5	-6	-30		180
10-12	11.5	4	-7	-28		196
7-9	8.5	7	-8	-56	(-226)	448
	N=	116				2,361

GA = 32.5

$c = \frac{-39}{116} = -.3363 \quad c^2 = .1131$

C= -.3363 x 3 = -1.009

Average 32.5-1.009 - 31.49

$$\sigma = \sqrt{\frac{\Sigma FD^2}{N} - C^2}$$

$$\sigma = \sqrt{\frac{2361}{116} - .1131} \times 3 = 13.49$$

TABLE XIX

Grade XII

Corrected Scores

Country

BOYS — Rockport and Hanover | **GIRLS** — Rockport and Hanover

Scores	Midpoint	F	D	FD	FD^2	F	D	FD	FD^2
76-78	77.5	1	12	12	144				
73-75	74.5	0	11	0	0				
70-72	71.5	1	10	10	100				
67-69	68.5	0	9	0	0				
64-66	65.5	0	8	0	0	1	13	13	169
61-63	62.5	1	7	7	49	0	12	0	0
58-60	59.5	0	6	0	0	0	11	0	0
55-57	56.5	1	5	5	25	0	10	0	0
52-54	53.5	0	4	0	0	0	9	0	0
49-51	50.5	2	3	6	18	0	8	0	0
46-48	47.5	2	2	4	8	1	7	7	49
43-45	44.5	3	1	3(+47)	3	0	6	0	0
40-42	41.5	5				2	5	10	50
37-39	38.5	1	-1	-1	1	0	4	0	0
34-36	35.5	1	-2	-2	4	3	3	9	27
31-33	32.5	4	-3	-12	36	2	2	4	8
28-30	29.5	3	-4	-12	48	2	1	2(+45)	2
25-27	26.5	4	-5	-20	100	3			
22-24	23.5	1	-6	- 6(-53)	36	1	-1	1	1
19-21	20.5	N=30		100	572	5	-2	-10	20
16-18	17.5					2	-3	- 6	18
13-15	14.5					3	-4	-12	48
10-12	11.5					1	-5	- 5	25
7-9	8.5					5	-6	- 30(-64)	180
						N=31	C=1.8387		597

GA=41.5

$c = \frac{-6}{30} = -.2 \quad c^2 = .04$

C= -.2x3= -.6

GA=26.5 $c = \frac{-19}{31} = -.6129$ c=.3755

Average = 41.5+(-.6) = 40.9

$\sigma = \sqrt{\frac{572}{30} - .04} \times 3 = 13.08$

Average = 26.5-1.8387-25.66

$\sigma = \sqrt{\frac{597}{\sqrt{31}} - .3755} \times 3 = 13.04$

68 % between 54+28

Boys: $\sigma av - \frac{13.08}{\sqrt{30}} = 2.388$

Girls: $\sigma av = \frac{13.04}{\sqrt{31}} = 2.342$

40.90	av.Boys
25.66	av.Girls
15.24	difference

$\sigma diff = \sqrt{(.2388)^2\ (.2342)^2} = 3.344$

Chances are 68 in 100 that the obtained difference of 15 does not diverge from the true difference by more than ±3.344

Chances are 99 in 100 that 15 does not differ from the true difference by more than 3x±3.344 ;i.e., true difference lies between 18.34 and 11.66 .

TABLE XX

Grade XII

Corrected Scores

Boys **City** **Girls**

Brookline and Medford — Brookline and Medford

Scores	Midpoint	F	D	FD	FD^2	F	D	FD	FD^2
49-51	50.5	1	6	6	36				
46-48	47.5	2	5	10	50				
43-45	44.5	4	4	16	64				
40-42	41.5	3	3	9	27	1	5	5	25
37-39	38.5	4	2	8	16	5	4	20	80
34-36	35.5	1	1	1 (50)	1	1	3	3	9
31-33	32.5	4				1	2	2	4
28-30	29.5	1	-1	-1	1	3	1	3 (33)	3
25-27	26.5	2	-2	-4	8	4			
22-24	23.5	2	-3	-6	18	3	-1	-3	3
19-21	20.5	2	-4	-8	32	2	-2	-4	8
16-18	17.5	0	-5	0	0	2	-3	-6	18
13-15	14.5	2	-6	-12	72	0	-4	0	0
10-12	11.5	1	-7	- 7	49	2	-5	-10	50
7-9	8.5	1	-8	- 8 (-46)	64	1	-6	- 6 (-29)	36
		N=30		96	438	N=25		62	236

G.A. = 32.5

$c = \frac{4}{30} = .1333 \quad C^2 = .0178$

$C = .1333 \times 3 = .3999$

Average = 32.5 + .3999 = 32.90

$\sigma = \sqrt{\frac{\Sigma FD^2}{N} - c^2}$

$\sigma = \sqrt{\frac{438}{30} - .0178 \times 3} = 11.49$

G.A. = 26.5

$c = \frac{64}{25} = .16 \quad C^2 = .0256$

$C = .16 \times 3 = .48$

Average = 26.5 - .48 = 26.02

$\sigma = \sqrt{\frac{\Sigma FD^2}{N} - c^2}$

$\sigma = \sqrt{\frac{236}{25} - .256 \times 3} = 9.20$

32.90 av. Boys
26.02 av. Girls
6.88 diff

$\sigma av = \frac{\sigma dis}{\sqrt{N}}$

Boys $\sigma av = \frac{11.49}{\sqrt{30}} = 2.116$

Girls $\sigma av = \frac{9.20}{\sqrt{25}} = 1.840$

$\sigma diff = \sqrt{\sigma^2 av1 + \sigma^2 av.2}$

$\sigma diff = \sqrt{(2.116)^2 + (1.840)^2} = 2.808$

Chances are 68 in 100 that the obtained difference of 6.88 does not differ from the true difference by more than ± 2.808. Chances are 99 in 100 that 6.88 does not differ from the true difference by more than3x ± 2.808 i.e. true difference lies between 15.30 and -1.54. Since the lower limit of this range is negative, there is at least some chance that the true difference is less than 0. We cannot be 100% sure that the true difference between the average boy and girl (city) is greater than 0.

TABLE XXI

Grade XII

Corrected Scores
Comparison of City and Country Scores
BOYS

	No.of cases	Average Score	(dis)
Country	30	40.90	13.08
City	30	32.90	11.49

40.90 av. country
32.90 av. city
8.00 Difference

$\sigma av = \frac{\sigma dis}{\sqrt{N}}$ country $= \sigma av - \frac{13.08}{\sqrt{30}} = 2.388$

city $= \sigma av = \frac{11.49}{\sqrt{30}} = 2.116$

$\sigma diff = \sqrt{\sigma^2 av.1 + \sigma^2 av.2}$

$$\sigma diff = \sqrt{(2.388)^2 + (2.116)^2} = 3.683$$

Chances are 68 in 100 that 8.00 does not differ from the true difference by more than ± 3.683 .
Chances are 99 in 100 that 8 does not differ from the true difference by more than 3 x±3.683 . True difference lies between 19.05 and -3.05. We can not be certain that the true difference between city and country is greater than 0. (In (2.17σ) 98% of cases country boys exceed city boys.)

GIRLS

	No. of cases	Average Score	(dis)
Country	31	25.89	13.04
City	25	26.02	9.20

26.02 City
25.66 Country
.36 Difference

$\sigma av = \frac{\sigma dis}{\sqrt{N}}$ country $\sigma av = \frac{13.04}{\sqrt{31}} = 2.342$

city $\sigma av = \frac{9.20}{\sqrt{25}} = 1.840$

$\sigma diff = \sqrt{\sigma^2 av\ 1 + \sigma^2 av\ 2}$

$\sigma diff = \sqrt{(2.342)^2 + (1.840)^2} = 2.98$

Chances are 68 in 100 that .36 does not differ from the true difference by more than ±2.98 .
Chances are 99 in 100 that .36 does not differ from the true difference by more than 3 x ±2.98 . True difference lies between + 9.30 and -8.58.

TABLE XXII

Grade XI

Corrected Scores

Country

	BOYS Rockport and Hanover	GIRLS Rockport and Hanover
1.	40.89	25.00
2.	43.45	40.89
3.	35.22	24.34
4.	27.22	16.78
5.	31.66	42.22
6.	46.67	47.45
7.	27.67	22.22
8.	30.78	25.11
9.	63.89	14.67
10.	27.56	36.56
11.	57.00	41.56
12.	22.11	12.33
13.	19.00	34.11
14.	59.78	14.78
15.	57.44	28.11
16.	14.67	23.22
17.	30.22	24.33
18.	53.89	29.44
19.	45.45	17.22
20.	47.45	34.89
21.	44.00	5.78
22.	43.00	46.33
23.	24.11	7.55
24.	20.89	9.55
25.	38.78	26.33
26.	37.78	14.22
27.	26.89	
28.	48.78	
29.	33.44	
30.	33.56	
31.	47.22	
32.	48.69	
33.	51.56	

Range = 46.33-5.78 = 40.55

Range = 63.89-14.67 = 49.22

TABLE XXIII

Grade XI

Corrected Scores

City

	BOYS Brookline and Medford	GIRLS Brookline and Medford
1.	21.55	26.22
2.	41.00	20.68
3.	31.22	11.00
4.	51.22	14.00
5.	45.33	3.76
6.	3.78	19.78
7.	32.00	32.67
8.	32.00	18.11
9.	30.89	18.00
10.	11.67	23.67
11.	43.22	17.56
12.	15.45	32.00
13.	19.22	27.67
14.	27.55	8.44
15.	40.33	21.11
16.	37.34	9.22
17.	43.00	33.78
18.	44.89	38.45
19.	9.89	9.89
20.	43.89	2.67
21.	9.89	4.67
22.	28.56	14.00
23.	28.11	14.00
24.	14.33	21.67
25.	16.89	16.44
26.	32.22	19.89
27.	46.67	13.22
28.	43.78	12.67
29.	30.11	15.11
30.	30.67	14.67
31.	16.44	17.34
32.	11.89	5.67
33.	51.45	9.22

Range=51.22 -3.78= 47.44

Range= 38.45-2.67=35.78

TABLE XXIV

Grade XI

Corrected Scores

Boys, Girls, City and Country

Scores	Midpoint	F	D	FD	FD^2
61-62	62.5	1	12	12	144
58-60	59.5	1	11	11	121
55-57	56.5	2	10	20	200
52-54	53.5	1	9	9	81
49-51	50.5	3	8	24	192
46-48	47.5	7	7	49	343
43-45	44.5	11	6	66	396
40-42	41.5	6	5	30	150
37-39	38.5	4	4	16	64
34-36	35.5	4	3	12	36
31-33	32.5	10	2	20	40
28-30	29.5	9	1	9 (+278)	9
25-27	26.5	10			
22-24	23.5	7	-1	-7	7
19-21	20.5	9	-2	-18	36
16-18	17.5	9	-3	-27	81
13-15	14.5	12	-4	-48	192
10-12	11.5	5	-5	-25	125
7-9	8.5	8	-6	-48	288
4-6	5.5	3	-7	-21	147
1-3	2.5	3	-8	-24 (-218)	192
		N = 125			2844

GA = 26.5

$c = \frac{+60}{125} = .48 \quad C^2 = .2304$

C = .48 x 3 = 1.44

Average = 26.5 + 1.44 = 27.94

$$\sigma = \sqrt{\frac{\Sigma FD^2}{N} - C^2} \times 3$$

$$\sigma = \sqrt{\frac{2844}{125} - .2304} \times 3$$

σ = 14.24

TABLE XXV

Grade XI

Corrected Scores

Country

		Boys Rockport and Hanover				Girls Rockport and Hanover			
Scores	Midpoint	F	D	FD	FD^2	F	D	FD	FD^2
61-63	62.5	1	8	8	64				
58-60	59.5	1	7	7	49				
55-57	56.5	2	6	12	72				
52-54	53.5	1	5	5	25				
49-51	50.5	1	4	4	16				
46-48	47.5	4	3	12	36	2	7	14	98
43-45	44.5	5	2	10	20	0	6	0	0
40-42	41.5	1	1	1(59)	1	3	5	15	75
37-39	38.5	2				0	4	0	0
34-36	35.5	1	-1	-1	1	3	3	9	27
31-33	32.5	3	-2	-6	12	0	2	0	0
28-30	29.5	2	-3	-6	18	2	1	2(+40)	2
25-27	28.5	4	-4	-16	64	3			
22-24	23.5	2	-5	-10	50	4	-1	-4	4
19-21	20.5	2	-6	-12	72	0	-2	0	0
16-18	17.5	0	-7	0	0	2	-3	-6	18
13-15	14.5	1	-8	-8(-59)	64	3	-4	-12	48
10-12	11.5	N=33			564	1	-5	-5	25
7-9	8.5					2	-6	-12	72
4-6	5.5					1	-7	-7(-46)	49
						N=26			418

GA = 38.5
c = 0 c2 = 0
C = 0 x 3 = 0

Average = 38.5

GA = 26.5
$c = \frac{-6}{26} = .2308 \quad c^2 = .0533$
C = .2308 x 3 = .6924
Average = 26.5 — .6924 = 25.81

$$\sigma = \sqrt{\frac{564}{33} - 0^2} \times 3 = 12.40$$

$$\sigma = \sqrt{\frac{418}{26} - .0533} \times 3 = 12.01$$

38.50 av Boys
25.81 av Girls
12.69

$$\sigma\,\text{diff} = \sqrt{\sigma^2 \text{av.}1 + \sigma^2 \text{av.}2}$$

$$\sigma\,\text{av} = \frac{\sigma\,\text{dis}}{\sqrt{N}}$$

$$\sigma\,\text{diff} = \sqrt{(2.16)^2 + (2.36)^2}$$

$$\text{Boys } \sigma\,\text{av} = \frac{12.40}{\sqrt{33}} = 2.16$$

$$\sigma\,\text{diff} = 3.20$$

$$\text{Girls } \sigma\,\text{av} = \frac{12.01}{\sqrt{26}} = 2.36$$

TABLE XXVI

Grade XI

Corrected Scores

City

		Boys				**Girls**			
		Brookline and Medford				**Brookline and Medford**			
Scores	Midpoint	F	D	FD	FD^2	F	D	FD	FD^2
49-51	50.5	2	7	14	98				
46-48	47.5	1	6	6	36				
43-45	44.5	6	5	30	150				
40-42	41.5	2	4	8	32				
37-39	38.5	1	3	3	9	1	7	7	49
34-36	35.5	0	2	0	0	0	6	0	0
31-33	32.5	4	1	4 (65)	4	3	5	15	75
28-30	29.5	5				0	4	0	0
25-27	26.5	1	-1	-1	1	2	3	6	18
22-24	23.5	0	-2	-0	0	1	2	2	4
19-21	20.5	2	-3	-6	18	5	1	5 (35)	5
16-18	17.5	2	-4	-8	32	5			
13-15	14.5	2	-5	-10	50	6	-1	6	6
10-12	11.5	2	-6	-12	72	2	-2	4	8
7-9	8.5	2	-7	-14	98	4	-3	12	36
4-6	5.5	0	-8	-0	0	2	-4	8	32
1-3	2.5	1	-9	-9 (-60)	81	2	-5	10 (-40)	50
		N = 33			681	N = 33			283

GA = 29.5

$c = \frac{5}{33} = .1515$ $c^2 = .023$

$C = .1515 \times 3 = .4545$

Average = 29.95

$$\sigma = \sqrt{\frac{\Sigma FD^2}{N} - C^2} \times 3$$

$$\sigma = \sqrt{\frac{681}{33} - .023} \times 3 = 13.62$$

13.62 av. Boys
8.77 av. Girls
4.85

$$\sigma \text{ av.} = \frac{\sigma \text{dis}}{\sqrt{N}}$$

$$\sigma(\text{Boys}) \text{ av} = \frac{13.62}{\sqrt{33}} = 2.37$$

$$\sigma(\text{Girls}) \text{ av} = \frac{8.77}{\sqrt{33}} = 1.53$$

GA = 17.5

$c = \frac{-5}{33} = -.1515$ $c^2 = .023$

$C = -.1515 \times 3 = -.4545$

Average = 17.06

$$\sigma = \sqrt{\frac{\Sigma FD^2}{N} - C^2} \times 3$$

$$\sigma = \sqrt{\frac{283}{33} - .023} \times 3 = 8.77$$

$$\sigma \text{diff} = \sqrt{\sigma^2 \text{av1} + \sigma^2 \text{av2}}$$

$$\sigma \text{ diff} = \sqrt{(2.37)^2 + (1.53)^2}$$

$$\sigma \text{ diff} = 2.82$$

TABLE XXVII

Grade XI

Corrected Scores

Comparison of City and Country Scores

Boys

	No. of cases	Average Scores	σdis
Country	33	38.5	12.40
City	33	29.95	13.62

38.50 av. country
29.95 av. city
8.55

$$\sigma av = \frac{dis}{\sqrt{N}} \qquad \text{country } \sigma av = \frac{12.40}{\sqrt{33}} = 2.16$$

$$\text{city } \sigma av = \frac{13.62}{\sqrt{33}} = 2.37$$

$$\sigma \text{ diff} = \sqrt{\sigma av1^2 + \sigma av2^2}$$

$$\sigma \text{ diff} = \sqrt{(2.16)^2 + (2.37)^2} = 3.20$$

Girls

	No. of cases	Average Score	dis
country	26	25.81	12.01
city	33	17.06	8.77

25.81 av. country
17.06 av. city
8.75 diff

$$\sigma av = \frac{dis}{\sqrt{N}} \qquad \text{country } \sigma av. = \frac{12.01}{\sqrt{26}} = 2.$$

$$\text{city } \sigma av = \frac{8.77}{\sqrt{33}} = 1.53$$

$$\sigma \text{ diff} = \sqrt{\sigma av1^2 + \sigma av2^2}$$

$$\sigma \text{ diff} = \sqrt{(2.36)^2 + (1.53)^2}$$

$$\sigma \text{ diff} = 2.82$$

TABLE XXVIII

Grade X

Corrected Scores

BOYS Rockport and Hanover		Country	GIRLS Rockport and Hanover
1.	49.78		17.55
2.	21.00		27.44
3.	27.34		17.89
4.	38.00		6.11
5.	35.69		17.55
6.	23.78		14.56
7.	39.00		22.66
8.	20.78		8.11
9.	32.33		20.89
10.	31.00		46.89
11.	38.78		33.22
12.	43.11		12.00
13.	63.67		4.44
14.	37.00		33.89
15.	48.56		30.00
16.	39.22		23.89
17.	40.00		6.78
18.	18.22		25.78
19.	49.45		9.44
20.	34.00		7.56
21.	33.66		11.78
22.	30.44		14.78
23.	24.44		30.66
24.	36.44		18.33
25.	38.78		22.00
26.	70.22		11.89
27.	29.45		29.89
28.	36.22		11.11
29.	31.22		16.55
30.	30.00		15.22
31.	42.22		14.67
32.	21.67		15.44
33.	14.67		6.33
34.	46.67		25.77
35.	28.45		
36.	24.00		

Range = 70.22 - 14.67 = 55.55   Range = 46.89 - 4.44 = 42.45

TABLE XXIX

Grade X

Corrected Scores

City

	BOYS Brookline and Medford	GIRLS Brookline and Medford
1.	59.67	25.22
2.	35.89	36.44
3.	26.78	20.33
4.	41.11	18.33
5.	4.78	39.44
6.	30.55	35.22
7.	54.45	27.87
8.	48.11	14.78
9.	59.11	12.22
10.	20.00	23.44
11.	38.56	13.89
12.	43.78	25.22
13.	36.11	11.66
14.	28.55	16.44
15.	40.56	13.22
16.	12.22	20.89
17.	15.00	7.50
18.	13.22	25,11
19.	26.11	16.89
20.	41.67	12.44
21.	31.67	6.45
22.	32.00	5.17
23.	27.89	11.56
24.	40.33	28.11
25.	37.55	10.67
26.	40.89	11.67
27.	40.56	40.00
28.	26.89	11.33
29.	12.11	
30.	25.56	
31.	22.44	
32.	11.22	
33.	56.89	
34.	29.22	
35.	38.89	

Range = 59.67 - 4.78 = 54.89 Range = 40.00 - 5.17 = 34.83

TABLE XXX

Grade X

Corrected Scores

Boys, Girls, City and Country

Scores	Midpoint	F	D	FD	FD^2
70-72	71.5	1	14	14	196
67.-69	68.5	0	13	0	0
64-66	65.5	0	12	0	0
61-63	62.5	1	11	11	121
58-60	59.5	2	10	20	200
55-57	56.5	1	9	9	81
52-54	53.5	1	8	8	64
49-51	50.5	2	7	14	98
46-48	47.5	4	6	24	144
43-45	44.5	2	5	10	50
40-42	41.5	9	4	36	144
37-39	38.5	10	3	30	90
34-36	35.5	8	2	16	32
31-33	32.5	8	1	8 (+ 200)	8
28-30	29.5	11			
25-27	26.5	13	-1	-13	13
22-24	23.5	8	-2	-16	32
19-21	20.5	7	-3	-21	63
16-18	17.5	9	-4	-36	144
13-15	14.5	11	-5	-55	275
10-12	11.5	14	-6	-84	504
7-9	8.5	4	-7	-28	196
4-6	5.5	7	-8	-56 (-309)	448
1-3	2.5	0			2903
		N = 133			

GA = 29.5

$c = \frac{-109}{133} = -.8166 \quad c^2 = .6668$

C = -.8166 x3 = 2.45

Average = 29.5 - 2.45 = 27.05

$$\sigma = \sqrt{\frac{FD^2}{N} - c^2}$$

$$\sigma = \sqrt{\frac{2903}{133} - .6668} \times 3 = 13.83$$

TABLE XXXI

Grade X

Corrected Scores

Country

Boys						Girls			
Rockport and Hanover						Rockport and Hanover			
Scores	Midpoint	F	D	FD	FD^2	F	D	FD	FD^2
72-75	74.1	0							
70-72	71.5	1	11	11	121				
67-69	68.5	0	10	0	0				
64-66	65.5	0	9	0	0				
61-63	62.5	1	8	8	64				
58-60	59.5	0	7	0	0				
55-57	56.5	0	6	0	0				
52-54	53.5	0	5	0	0				
49-51	50.5	2	4	8	32				
46-48	47.5	2	3	6	18	1	10	10	100
43-45	44.5	1	2	2	4	0	9	0	0
40-42	41.5	2	1	2(37)	2	0	8	0	0
37-39	38.5	6				0	7	0	0
34-36	35.5	4	-1	-4	4	0	6	0	0
31-33	32.5	4	-2	-8	16	2	5	10	50
28-30	29.5	4	-3	-12	36	3	4	12	48
25-27	26.5	1	-4	- 4	16	3	3	9	27
22-24	23.5	3	-5	-15	75	3	2	6	12
19-21	20.5	3	-6	-18	108	1	1	1(48)	1
16-18	17.5	1	-7	- 7	49	5			
13-15	14.5	1	-8	- 8(-76)	64	5	-1	-5	5
10-12	11.5	0			609	4	-2	-8	16
7-9	8.5	0				3	-3	-9	27
4-6	5.5	0				4	-4	-16 (-38)	64
1-3	2.5	0				0			350
	N=	36				N= 34			

G.A. = 38.5

G.A. = 17.5
2

$c = \frac{-39}{36} = -1.0831$ $c = 1.1729$

$c = \frac{10}{34} = .2941$ $c = .08745$

C = -1.0831 x 3 = -3.2493

Average = 38.5 - 3.2493 = 35.25

C = .2941 x 3 = .8823

Average = 17.5 + .8823 = 18.38

$\sigma = \sqrt{\frac{\Sigma FD^2}{N} - C^2} \times 3 = \sqrt{\frac{609}{36} - 1.1729} \times 3 = 11.90$

$\sigma = \sqrt{\frac{\Sigma FD^2}{N} - C^2} \times 3 = \frac{350}{34} - 08745 \times 3 = 9.5$

Boys σ av = $\frac{11.90}{\sqrt{36}} = 1.983$

Girls σ av = $\frac{9.58}{\sqrt{34}} = 1.643$

35.25 av Boys
18.38 av Girls
16.87

$\sigma \text{ av} = \frac{\sigma \text{ dis}}{\sqrt{N}}$

$\sigma \text{ diff} = \sqrt{\sigma^2 \text{av1} + \sigma^2 \text{av2}}$

$\sigma \text{ diff} = \sqrt{(1.983)^2 + (1.643)^2} = 2.58$

TABLE XXXII

Grade X

Corrected Scores

City

		Boys Brookline and Medford				Girls Brookline and Medford			
Scores	Midpoint	F	D	FD	FD^2	F	D	FD	FD^2
58-60	59.5	2	9	18	162				
55-57	56.5	1	8	8	64				
52-54	53.5	1	7	7	49				
49-51	50.5	0	6	0	0				
46-48	47.5	1	5	5	25				
43-45	44.5	1	4	4	16				
40-42	41.5	6	3	18	54	1	7	7	49
37-39	38.5	3	2	6	12	1	6	6	36
34-36	35.5	2	1	2(68)	2	2	5	10	50
31-33	32.5	2				0	4	0	0
28-30	29.5	3	-1	-3	3	1	3	3	9
25-27	26.5	5	-2	-10	20	4	2	8	16
22-24	23.5	1	-3	- 3	9	1	1	1(35)	1
19-21	20.5	1	-4	- 4	16	2			
16-18	17.5	0	-5	0	0	3	-1	-3	3
13-15	14.5	2	--6	-12	72	3	-2	-6	12
10-12	11.5	3	- 7	-21	147	7	-3	-21	63
7-9	8.5	0	- 8	0	0	1	-4	- 4	16
4-6	5.5	1	-9	9(-62)	81	2	-5	-10(-44)	50
		N =35			732	N=28			305

G.A. = 32.5

$c = \frac{6}{35} = .1714 \quad c^2 = .0294$

C = .1714 x3 = .5142 = 33.01

Average = 32.5 + .5142 = 33.01

$\sigma = \sqrt{\frac{\Sigma FD^2}{N} - c^2} \times 3 = \sqrt{\frac{732}{35} - .0294} \times 3 = 13.70$

G.A. = 20.5

$c = \frac{-9}{28} = .3214 \quad c^2 = .1033$

C = .3214 x 3 = .9642

Average = 20.5 - .9642 = 19.54

$\sigma = \sqrt{\frac{\Sigma FD^2}{N} - c^2} \times 3 = \sqrt{\frac{305}{28} - .1033} \times 3 = 9.85$

33.01	av Boys
19.54	av Girls
13.47	diff

$\text{av} - \frac{\text{dis}}{N}$

$\text{Boys } \sigma \text{ av} = \frac{13.70}{\sqrt{35}} = 2.32$

$\text{Girls } \sigma \text{ av} = \frac{9.85}{\sqrt{28}} = 1.86$

$\sigma \text{ diff} = \sqrt{\sigma^2 \text{av1} + \sigma^2 \text{av2}}$

$\sigma \text{ diff} = \sqrt{(2.33)^2 + (1.86)^2}$

$\sigma \text{ diff} = 2.97$

TABLE XXXIII

Grade X

Corrected Scores

Comparison of City and Country Scores

BOYS

	No.of cases	average score	σdis
Country	36	35.25	11.90
City	35	33.01	13.70

35.25 av
33.01 av
2.24 diff

$$\sigma \text{av} = \frac{\text{dis}}{\sqrt{N}}$$

$$\text{country } \sigma \text{av} = \frac{11.90}{\sqrt{36}} = 1.983$$

$$\text{city } \sigma \text{av} = \frac{13.70}{\sqrt{35}} = 2.32$$

$$\sigma \text{diff} = \sqrt{\sigma^2 \text{av1} + \sigma^2 \text{av2}}$$

$$\sigma \text{diff} = \sqrt{(1.98)^2 + (2.32)^2}$$

$$\sigma \text{diff} = 3.05$$

GIRLS

	No. of cases	average score	dis
Country	34	18.38	9.58
City	28	19.54	9.85

19.54 av.
18.38 av.
-.16 diff.

$$\sigma \text{ av} = \frac{\sigma \text{dis}}{\sqrt{N}}$$

$$\text{country } \sigma \text{av} = \frac{9.58}{\sqrt{34}} = 1.64$$

$$\text{city } \sigma \text{av} = \frac{9.85}{\sqrt{28}} = 1.86$$

$$\sigma \text{diff} = \sqrt{\sigma^2 \text{av1} + \sigma^2 \text{av2}}$$

$$\sigma \text{diff} = \sqrt{(1.64)^2 + (1.86)^2}$$

$$\sigma \text{diff} = 2.48$$

TABLE XXXIV

Grade IX

Corrected Scores

Country

	BOYS Rockport and Hanover	GIRLS Rockport and Hanover
1.	29.56	13.00
2.	7.67	13.45
3.	11.89	21.11
4.	13.33	4.33
5.	36.56	15.11
6.	8.33	19.56
7.	16.00	37.00
8.	7.66	30.66
9.	10.89	6.22
10.	25.33	6.22
11.	22.22	18.22
12.	10.89	9.44
13.	11.78	17.67
14.	45.00	17.67
15.	31.89	16.45
16.	29.79	25.33
17.	22.22	25.47
18.	23.56	15.11
19.	13.55	13.44
20.	21.56	15.56
21.	25.67	36.22
22.	21.11	14.44
23.	40.78	21.33
24.	14.67	25.44
25.	29.01	20.67
26.	23.56	24.56
27.	27.33	16.55
28.	52.67	17.11
29.	37.78	11.89
30.	43.67	17.33
31.	7.55	17.33
32.	49.89	15.44
33.	35.11	13.79
34.	11.84	22.55
35.	17.44	22.33
36.	40.67	26.45
37.	30.78	11.67
38.	51.78	
39.	33.78	

TABLE XXXV

Grade IX

Corrected Scores

City

	Boys Brookline and Medford	Girls Brookline and Medford
1.	26.45	18.67
2.	12.00	14.22
3.	45.00	12.55
4.	18.78	12.89
5.	36.56	7.67
6.	19.00	14.22
7.	40.56	14.00
8.	16.33	17.44
9.	60.22	22.78
10.	15.33	9.00
11.	28.67	8.01
12.	27.67	17.45
13.	41.11	8.00
14.	12.01	21.83
15.	8.00	8.45
16.	30.67	16.56
17.	42.00	5.78
18.	18.11	10.00
19.	3.56	15.22
20.	27.78	23.67
21.	21.78	14.89
22.	24.56	10.67
23.	34.11	22.78
24.	17.11	12.33
25.	28.33	
26.	28.33	
27.	34.67	
28.	6.22	
29.	28.17	
30.	22.56	
31.	46.78	
32.	25.22	
33.	12.44	
34.	26.44	

Range=60.22 - 3.56 = 56.66

Range=23.67 - 5.78 = 17.89

TABLE XXXVI

Grade IX

Corrected Scores

Boys, Girls, City and Country

Scores	Midpoint	F	D	FD		FD^2
58-60	59.5	1	13	13		169
55-57	56.5	0	12	0		0
52-54	53.5	1	11	11		121
49-51	50.5	2	10	20		200
46-48	47.5	1	9	9		81
43-45	44.5	3	8	24		192
40-42	41.5	5	7	35		245
37-39	38.5	2	6	12		72
34-36	35.5	6	5	30		150
31-33	32.5	2	4	8		32
28-30	29.5	10	3	30		90
25-27	26.5	12	2	24		48
22-24	23.5	12	1	12	(+228)	12
19-21	20.5	9				
16-18	17.5	18	-1	-18		+18
13-15	14.5	18	-2	-36		72
10-12	11.5	15	-3	-45		135
7-9	8.5	11	-4	-44		174
4-6	5.5	5	-5	-25		125
1-3	2.5	1	-6	-6	(-174)	36
		N= 134				1972

G.A. = 20.5

$c = \frac{54}{134} = .4029 \quad c^2 = .1623$

C = .4029 x 3 = 1.2087

Average 20.5 − 1.2087 = 21.71

$$\sigma = \sqrt{\frac{\Sigma FD^2}{N} - C^2}$$

$$\sigma = \sqrt{\frac{1972}{134} - .1623} \times 3 = 11.44$$

TABLE XXXVII

Grade IX

Corrected Scores

Country

		Boys				Girls			
		Rockport and Hanover				Rockport and Hanover			
Scores	Midpoint	F	D	FD	FD^2	F	D	FD	FD^2
52-54	53.5	1	10	10	100				
49-51	50.5	2	9	18	162				
46-48	47.5	0	8	0	0				
43-45	44.5	2	7	14	98				
40-42	41.5	2	6	12	72				
37-39	38.5	1	5	5	25	1	7	7	49
34-36	35.5	2	4	8	32	1	6	6	36
31-33	32.5	2	3	6	18	0	5	0	0
28-30	29.5	4	2	8	16	1	4	4	16
25-27	26.5	3	1	3(84)	3	4	3	12	36
22-24	23.5	4				3	2	6	12
19-21	20.5	2	-1	-2	2	4	1	4 (39)	4
16-18	17.5	2	-2	-4	8	8			
13-15	14.5	3	-3	-9	27	9	-1	-9	9
10-12	11.5	5	-4	-20	80	2	-2	-4	8
7-9	8.5	4	-5	-20(-55)	100	1	-3	-3	9
4-6	5.5	0			743	3	-4	-12(-28)	48
1-3	2.5	0				0			227
		N= 39				N= 37			

G.A. = 23.5

$c = \frac{29}{39} = .7436 \quad c^2 = .5519$

C - .7436 x 3 - 2.2308

Average = 23.5 + 2.2308 = 25.73

$$\sigma = \sqrt{\frac{\Sigma FD^2}{N} - c^2}$$

$$\sigma = \sqrt{\frac{743}{39} - .5519} \times 3 = 12.91$$

25.73 av Boys
18.39 av Girls
7.34 diff

$\sigma av = \frac{\sigma dis}{\sqrt{N}}$

$$\sigma \text{ diff} = \sqrt{\sigma^2 av1 + \sigma^2 av2}$$

$$\sigma \text{ diff} = \sqrt{(2.06)^2 + (.99)^2}$$

σ diff. = 2.29

G.A. = 17.5

$c = \frac{11}{37} = .2973 \quad c^2 = .0884$

C = .2973 x 3 = .8919

Average = 17.5 + .8919 = 18.39

$$\sigma = \sqrt{\frac{\Sigma FD^2}{N} - c^2}$$

$$\sigma = \sqrt{\frac{227}{37} - .0884} \times 3 - 6.03$$

Boys σ av- $\frac{12.91}{\sqrt{39}}$ = 2.06

Girls σ av - $\frac{6.03}{\sqrt{37}}$ = .99

TABLE XXXVIII

Grade IX

Corrected Scores

City

Boys Brookline and Medford Scores	Midpoint	F	D	FD	FD^2	Girls Brookline and Medford F	D	FD	FD^2
58-60	59.5	1	11	11	121				
55-57	56.5	0	10	0	0				
52-54	53.5	0	9	0	0				
49-51	50.5	0	9	0	0				
46-48	47.5	1	7	7	49				
43-45	44.5	1	6	6	36				
40-42	41.5	3	5	15	75				
37-39	38.5	0	4	0	0				
34-36	35.5	3	3	9	27				
31-33	32.5	0	2	0	0				
28-30	29.5	5	1	5(53)	5				
25-27	26.5	5							
22-24	23.5	2	-1	-2	2	3	3	9	27
19-21	20.5	2	-2	-4	8	1	2	2	4
16-18	17.5	4	-3	-12	36	4	1	4 (15)	4
13-15	14.5	1	-4	- 4	16	5			
10-12	11.5	3	-5	-15	75	5	-1	-5	5
7-9	8.5	1	-6	- 6	36	5	-2	-10	20
4-6	5.5	1	-7	- 7	49	1	-3	- 3 (-18)	6
1-3	2.5	1	-8	- 8(-58)	64	0			
		N= 34			599	=24			66

G.A. = 26.5

$c = \frac{5}{34} = .1471 \quad c^2 = .0216$

G.A. = 14.5

$c = \frac{-3}{24} = -.125 \quad c^2 = .0156$

C = .1471 x 3 = .4413

Average = 26.5 + .4413 = 26.94

C = -.125 x 3 = -.375

Average = 14.5 -.375 = 14.13

$$\sigma = \sqrt{\frac{\Sigma FD^2}{N} - c^2}$$

$$\sigma = \sqrt{\frac{599}{34} - .0216} \times 3 = 12.57$$

$$\sigma = \sqrt{\frac{\Sigma FD^2}{N} - c^2}$$

$$\sigma = \sqrt{\frac{66}{24} - .0156} \times 3 = 4.97$$

26.94 Boys
14.13 Girls
12.81 Diff

$$\sigma_{av} = \frac{\sigma_{dis}}{\sqrt{N}}$$

$$\text{Boys } \sigma_{av} = \frac{12.57}{\sqrt{34}} = 2.16$$

$$\text{Girls } \sigma_{av} = \frac{4.97}{\sqrt{24}} = 1.01$$

$$\sigma_{diff} = \sqrt{\sigma_{av1}^2 + \sigma_{av2}^2}$$

$$\sigma_{diff} = \sqrt{(2.16)^2 + (1.01)^2}$$

diff = 2.38

TABLE XXXIX

Grade IX

Corrected Scores

Comparison of City and Country Scores

Boys

	No.of Cases	Average Score	σ dis
Country	39	25.73	12.91
City	34	26.94	12.57

26.94 av city
25.73 av country
1.21 diff

$$\sigma \text{av} = \frac{\sigma \text{dis}}{\sqrt{N}}$$

$$(\text{country})\ \sigma \text{av} = \frac{12.91}{\sqrt{39}} = 2.06$$

$$(\text{city})\ \sigma \text{av} = \frac{12.57}{\sqrt{34}} = 2.16$$

$$\sigma \text{diff} = \sqrt{\sigma^2 \text{av1} + \sigma^2 \text{av2}}$$

$$\sigma \text{diff} = \sqrt{(2.06)^2 + (2.16)^2} = 2.98$$

Girls

	No. of Cases	Average Score	σ dis
Country	37	18.39	6.03
City	24	14.13	4.97

18.39 av country
14.13 av city
4.26 diff

$$\sigma \text{av} = \frac{\sigma \text{dis}}{\sqrt{N}}$$

$$(\text{country})\ \sigma \text{av} = \frac{6.03}{\sqrt{37}} = .99$$

$$(\text{city})\ \sigma \text{av} = \frac{4.97}{\sqrt{24}} = 1.01$$

$$\sigma \text{diff} = \sqrt{\sigma^2 \text{av1} + \sigma^2 \text{av2}}$$

$$\sigma \text{diff} = \sqrt{(.99)^2 + (1.01)^2} = 1.41$$

TABLE XL

Grade VIII

Corrected Scores

Country

	Boys	Girls
	Rockport and Hanover	Rockport and Hanover
1.	17.84	6.50
2.	11.67	4.50
3.	23.34	16.00
4.	13.00	19.84
5.	50.00	8.17
6.	32.89	11.50
7.	26.00	6.67
8.	24.84	25.67
9.	19.83	15.33
10.	27.34	26.17
11.	16.67	20.67
12.	41.67	2.84
13.	20.84	6.67
14.	44.00	4.67
15.	4.67	3.17
16.	27.34	7.67
17.	4.67	20.84
18.	9.16	9.84
19.	27.67	37.17
20.	38.84	11.17
21.	37.67	43.34
22.	40.00	15.17
23.	3.00	36.34
24.	50.33	23.33
25.	14.50	18.34
26.	17.33	7.50
27.	14.83	23.67
28.	20.00	18.00
29.	17.67	16.50
30.	18.67	16.50
31.	22.50	27.50
32.	38.50	19.17
33.	17.83	22.84
34.	16.89	20.17
35.	34.67	12.67
36.	17.17	17.67
37.	33.00	
38.	29.34	

Range =50.33-3.00 = 47.33

Range = -43.34-2.84 = 40.50

TABLE XLI

Grade VIII

Corrected Scores

City

	Boys	Girls
	Brookline and Medford	Brookline and Medford
1.	23.83	18.00
2.	14.34	27.84
3.	42.84	15.00
4.	41.17	9.34
5.	24.00	8.34
6.	22.34	29.34
7.	38.84	47.52
8.	30.00	44.17
9.	29.34	21.50
10.	32.00	10.84
11.	35.34	28.83
12.	45.34	25.00
13.	40.84	38.67
14.	46.33	19.00
15.	30.00	21.00
16.	57.17	33.34
17.	49.67	55.34
18.	30.17	22.17
19.	11.84	21.67
20.	26.50	15.84
21.	38.50	24.00
22.	16.17	40.00
23.	24.33	23.00
24.	10.00	10.17
25.	21.17	18.17
26.	27.67	13.67
27.	13.34	17.34
28.	16.84	1.50
29.	10.83	12.67
30.	29.34	33.34
31.	15.33	23.49
32.	37.33	10.00
33.	11.00	17.50
34.	3.34	22.00
35.	34.00	27.34
36.	28.00	17.34
37.	26.67	25.17
38.	55.67	
39.	21.33	
40.	28.50	
41.	9.34	

TABLE XLII

Grade VIII

Corrected Scores

Boys and Girls-City and Country

Scores	Midpoint	F	D	FD	FD^2
55-57	56.5	3	12	36	432
52-54	53.5	0	11	0	0
49-51	50.5	3	10	30	300
46-48	47.5	2	9	18	162
43-45	44.5	4	8	32	258
40-42	41.5	6	7	42	294
37-39	38.5	8	6	48	288
34-36	35.5	4	5	20	100
31-33	32.5	5	4	20	80
28-30	29.5	10	3	30	90
25-27	26.5	14	2	28	56
22-24	23.5	15	1	15 (+319)	15
19-21	20.5	14			
16-18	17.5	21	-1	-21	21
13-15	14.5	11	-2	-22	44
10-12	11.5	12	-3	-36	108
7-9	8.5	8	-4	-32	128
4-6	5.5	7	-5	-35	175
1-3	2.5	5	-6	-30(-176)	180
		N= 152			2729

G.A. = 20.5 $c = \frac{143}{152} = .9408$ $c^2 = .8851$

C = .9408 x 3 = 2.8224

Average = 20.5 + 2.8224 = 23.3

$$\sigma = \sqrt{\frac{\Sigma FD^2}{N} - c^2}$$

$$\sigma = \sqrt{\frac{2729}{152} - .8851} \times 3 = 4.13$$

TABLE XLIII

Grade VIII

Corrected Scores

Country

Boys — Rockport and Hanover | Girls — Rockport and Hanover

Scores	Midpoint	F	D	FD	FD^2	F	D	FD	FD^2
49-51	50.5	2	9	18	162				
46-48	47.5	0	8	0	0				
43-45	44.5	1	7	7	49	1	9	9	81
40-42	41.5	2	6	12	72	0	8	0	0
37-39	38.5	3	5	15	75	1	7	7	49
34-36	35.5	1	4	4	16	1	6	6	36
31-33	32.5	2	3	6	18	0	5	0	0
28-30	29.5	1	2	2	4	0	4	0	0
25-27	26.5	4	1	4(68)	4	3	3	9	27
22-24	23.5	3				3	2	6	12
19-21	20.5	3	-1	-3	3	5	1	5(42)	5
16-18	17.5	8	-2	-16	32	6			
13-15	14.5	3	-3	- 9	27	2	-1	-2	2
10-12	11.5	1	-4	- 4	16	3	-2	-6	12
7-9	8.5	1	-5	- 5	25	4	-3	-12	36
4-6	5.5	2	-6	-12	72	5	-4	-20	80
1-3	2.5	1	-7	- 7(-56)	49	2	-5	-10 (-50)	50
		N= 38			624	N=36			390

G.A. = 23.5

$c = \frac{12}{38} = .3158 \quad c^2 = .0997$

C = .3158 x 3 = .9474

Average = 23.5 + .9474 = 24.45

$\sigma = \sqrt{\frac{\Sigma FD^2}{N} - c^2}$

$\sigma = \sqrt{\frac{624}{38} - .0997} \times 3 = 12.12$

G.A. = 17.5

$c = \frac{-8}{36} = .2222 \quad c^2 = .0494$

C = .2222 x 3 = .6666

Average = 17.5 + .6666 = 18.17

$\sigma = \sqrt{\frac{\Sigma FD^2}{N} - c^2}$

$\sigma = \sqrt{\frac{390}{36} - .6666} \times 3 = 9.56$

12.12 av boys
9.56 av girls
2.56 Diff

$\sigma av = \frac{\sigma dis}{\sqrt{N}}$

Boys $\sigma av = \frac{12.12}{\sqrt{38}} = 1.97$

Girls $\sigma av = \frac{9.56}{\sqrt{36}} = 1.59$

$\sigma \text{ diff} = \sqrt{\sigma^2 av1 + \sigma^2 av2}$

$\sigma \text{ diff} = \sqrt{(1.97)^2 + (1.59)^2} = 2.53$

TABLE XLIV

Grade VIII

Corrected Scores

City

Boys Brookline and Medford						Girls Brookline and Medford			
Scores	Midpoint	F	D	FD	FD^2	F	D	FD	FD^2
55-57	56.5	2	10	20	200	1	11	11	121
52-54	53.5	0	9	0	0	0	10	0	0
49-51	50.5	1	8	8	64	0	9	0	0
46-48	47.5	1	7	7	49	1	8	8	64
43-45	44.5	1	6	6	36	1	7	7	49
40-42	41.5	3	5	15	75	1	6	6	36
37-39	38.5	3	4	12	48	1	5	5	25
34-36	35.5	2	3	6	36	0	4	0	0
31-33	32.5	1	2	2	4	2	3	6	18
28-30	29.5	7	1	7(83)	7	2	2	4	8
25-27	26.5	3				4	1	4(51)	4
22-24	23.5	4	-1	-4	4	5			
19-21	20.5	2	-2	-4	8	4	-1	-4	4
16-18	17.5	2	-3	-6	18	5	-2	±10	20
13-15	14.5	3	-4	-12	48	3	-3	-9	27
10-12	11.5	4	-5	-20	100	4	-4	±16	64
7-9	8.5	1	-6	- 6	36	2	-5	-10	50
4-6	5.5	0	-7	0	0	0	-6	0	0
1-3	2.5	1	-8	-8(-60)	64	1	-7	-7 (-56)	49
		N=41			797	N= 37			539

G A = 26.5

$c = \frac{23}{41} = .561 \quad c^2 = .3147$

C = .561 x 3 = 1.683

Average = 26.5 + 1.683 = 28.18

$\sigma = \sqrt{\frac{\Sigma FD^2}{N} - c^2}$

$\sigma = \sqrt{\frac{797}{41} - .3147} \times 3 = 13.11$

GA = 23.5

$c = \frac{-5}{37} = -.1351 \quad c^2 = .0183$

C = .1351 x 3 = .4053

Average = 23.5 +.4053 = 23.91

$\sigma = \sqrt{\frac{\Sigma FD^2}{N} - c^2}$

$\sigma = \sqrt{\frac{539}{37} -.0813} \times 3 = 11.43$

28.18 Boys
23.91 Girls
4.27 Diff

$\sigma av - \frac{\sigma dis}{\sqrt{N}}$

Boys $\sigma av = \frac{13.11}{\sqrt{41}} = 2.05$

Girls $\sigma av = \frac{11.43}{\sqrt{37}} = 1.88$

$\sigma diff = \sqrt{\sigma^2 av1 + \sigma^2 av2}$

$\sigma diff = \sqrt{(2.05)^2 + (1.88)^2} = 2.78$

TABLE XLV

Grade VIII

Comparison of City and Country Scores

Boys

	No. Of Cases	Average Score	dis
Country	38	24.45	12.12
City	41	28.18	13.11

City 28.18
Country 24.45
-3.73

$$\sigma \text{ av } {}^{*}= \frac{\sigma \text{dis}}{\sqrt{N}}$$

$$\text{country } \sigma \text{ av} = \frac{12.12}{38} = 1.97$$

$$\text{city } \sigma \text{ av} = \frac{13.11}{41} = 2.05$$

$$\sigma \text{ diff} = \sqrt{\sigma^2 \text{av1} + \sigma^2 \text{av2}}$$

$$\sigma \text{ diff} = \sqrt{(1.97)^2 + (2.05)^2} = 2.84$$

Girls

	No. of Cases	Average Score	dis
Country	36	18.17	9.56
City	37	23.91	11.43

City = 23.91
Country = 18.17
- 5.74

$$\sigma \text{ av} = \frac{\sigma \text{dis}}{\sqrt{N}}$$

$$\text{country } \sigma \text{ av} = \frac{9.56}{36} = 1.59$$

$$\text{city } \sigma \text{ av} = \frac{11.43}{37} = 1.88$$

$$\sigma \text{ diff} = \sqrt{\sigma^2 \text{av1} + \sigma^2 \text{av2}}$$

$$\sigma \text{ diff} = \sqrt{(1.59)^2 + (1.88)^2} = 2.46$$

TABLE XLVI

Grade VII

Corrected Scores

Country

	Boys	Girls
	Rockport and Hanover	Rockport and Hanover
1.	17.67	8.34
2.	14.67	10.17
3.	3.00	31.34
4.	15.39	13.34
5.	7.50	24.84
6.	18.33	6.84
7.	30.89	1.67
8.	17.83	10.00
9.	14.98	2.00
10.	40.17	1.67
11.	2.67	13.50
12.	18.33	21.67
13.	13.34	6.52
14.	18.33	12.83
15.	10.84	17.00
16.	33.50	1.67
17.	27.50	7.50
18.	20.67	18.17
19.	9.00	6.00
20.	20.34	5.17
21.	23.83	21.00
22.	7.84	11.50
23.	12.34	13.83
24.	15.67	21.00
25.	12.50	9.00
26.	16.34	11.84
27.	22.84	8.67
28.	8.67	12.67
29.	12.50	25.00
30.	24.00	5.83
31.	23.34	4.67
32.	11.34	4.50
33.	9.50	4.83
34.	46.83	
35.	6.00	
36.	15.00	
37.	6.00	
38.	10.83	

Range = 46.83-2.67 = 44.16

Range = 31.34-1.67 =29.67

TABLE XLVII

Grade VII

Corrected Scores

City

	Boys	Girls
	Brookline and Medford	Brookline and Medford
1.	51.00	16.50
2.	14.17	30.33
3.	8.00	19.50
4.	47.34	23.34
5.	38.67	26.33
6.	16.50	11.17
7.	15.50	21.50
8.	23.50	1.50
9.	36.50	
10.	17.84	22.00
11.	17.67	14.34
12.	18.17	10.50
13.	10.50	12.00
14.	27.17	8.17
15.	19.34	23.84
16.	22.83	9.67
17.	12.33	11.00
18.	42.50	5.84
19.	29.50	32.84
20.	25.50	14.17
21.	1.33	16.34
22.	10.67	14.67
23.	7.00	8.83
24.	19.50	11.00
25.	4.50	15.34
26.	20.00	10.50
27.	7.34	3.83
28.	8.83	17.34
29.	21.04	10.18
30.	20.17	18.00
31.	11.50	16.67
32.	11.50	23.34
33.	38.67	8.17
34.	5.17	22.50
35.	21.84	4.50
36.	8.33	6.84
37.	16.33	17.34
38.	8.84	5.84
39.	21.50	

Range = 51.00-1.33 = 49.67 Range = 32.84-1.5 = 31.34

TABLE XLVIII

Grade VII

Corrected Scores

Boys, Girls- City and Country

Scores	Midpoint	F	D	FD	FD^2
49-51	50.5	1	11	11	121
46-48	47.5	2	10	20	200
43-45	44.5	0	9	0	0
40-42	41.5	2	8	16	128
37-39	38.5	2	7	14	98
34-36	35.5	1	6	6	36
31-33	32.5	3	5	15	75
28-30	29.5	3	4	12	48
25-27	26.5	5	3	15	45
22-24	23.5	13	2	26	52
19-21	20.5	13	1	13 (148)	13
16-18	17.5	19			
13-15	14.5	15	-1	-15	15
10-12	11.5	24	-2	-48	96
7-9	8.5	19	-3	-57	171
4-6	5.5	17	-4	-68	272
1-3	2.5	8	-5	-40 (-228)	200
		N= 147			1568

G.A. - 17.5

$c = \frac{-80}{147} = -.5442 \quad c^2 = .2962$

Average = 17.5- 1.6326 = 15.87

$C = .5442 \times 3 = -1.6326$

$$\sigma = \pm\sqrt{\frac{\Sigma FD^2}{N} - C^2}$$

$$\sigma = \sqrt{\frac{1568}{147} - .2962} \times 3 = 9.66$$

TABLE XLIX

Grade VII

Corrected Scores

Country

Boys — Rockport and Hanover | **Girls** — Rockport and Hanover

Scores	Midpoint	F	D	FD	FD^2	F	D	FD	FD^2
46-48	47.5	1	11	11	121				
43-45	44.5	0	10	0	0				
40-42	41.5	1	9	9	81				
37-39	38.5	0	8	0	0				
34-36	35.5	0	7	0	0				
31-33	32.5	1	6	6	36	1	7	7	49
28-30	29.5	1	5	5	25	0	6	0	0
25-27	26.5	1	4	4	16	1	5	5	25
22-24	23.5	4	3	12	36	1	4	4	16
19-21	20.5	2	2	4	8	3	3	9	27
16-18	17.5	6	1	6 (57)	6	2	2	4	8
13-15	14.5	6	0			3	1	3 (32)	3
10-12	11.5	6	-1	-6	6	6			
7-9	8.5	5	-2	-10	20	4	-1	-4	4
4-6	5.5	2	-3	-6	18	8	-2	-16	32
1-3	2.5	2	-4	-8 (-30)	32	4	-3	-12 (-32)	36
		N= 38			404	N=33			200

Boys

G.A. = 14.5

$c = \frac{27}{28} = .7105 \quad c^2 = .4978$

C = .7105 x 3 = 2.1315

Average = 14.5 + 2.1315 = 16.63

$$\sigma = \sqrt{\frac{FD^2}{N} - C^2}$$

$$\sigma = \sqrt{\frac{404}{38} - .4978} \text{ x } 3 - 10.72$$

Girls

G.A. = 11.5

$c = \frac{0}{38} = c^2 = 0$

C = 0 x 3 = 0

Average = 11.5+0 = 11.5

$$\sigma = \sqrt{\frac{\Sigma FD^2}{N} - C^2}$$

$$\sigma = \sqrt{\frac{200}{33} - 0} \text{x } 3 - 7.38$$

16.63 av Boys
11.5 av Girls
5.13 Diff

$$av = \frac{\sigma dis}{\sqrt{N}}$$

(Boys) $\sigma av = \frac{10.72}{\sqrt{38}} = 1.74$

(Girls) $\sigma av = \frac{7.38}{\sqrt{33}} = 1.28$

$$\sigma diff = \sqrt{\sigma^2 av1 + \sigma^2 av2}$$

$$\sigma diff = \sqrt{(1.74)^2 + (1.28)^2} = 2.16$$

TABLE L

Grade VII

Corrected Scores

City

Boys						Girls			
Brookline and Medford						Brookline and Medford			
Score	Midpoint	F	D	FD	FD^2	F	D	FD	FD^2
49-51	50.5	1	11	11	121				
46-48	47.5	1	10	10	100				
43-45	44.5	0	9	0	0				
40-42	41.5	1	8	8	64				
37-39	38.5	2	7	14	98				
34-36	35.5	1	6	6	36				
31-33	32.5	0	5	0	0	1	6	6	36
28-30	29.5	1	4	4	16	1	5	5	25
25-27	26.5	2	3	6	18	1	4	4	16
22-24	23.5	3	2	6	12	5	3	15	45
19-21	20.5	6	1	6(71)	6	2	2	4	8
16-18	17.5	5				6	1	6(40)	6
13-15	14.5	2	-1	-1	1	4			
10-12	11.5	5	-2	-10	20	7	1	1	1
7-9	8.5	6	-3	-18	54	4	2	8	16
4-6	5.5	2	-4	- 8	32	5	3	15	45
1-3	2.5	1	-5	- 5(-42)	25	1	4	4 (28)	16
		N= 39			603	N=37			214

G.A. = 17.5

$c = \frac{29}{39} = .7436 \quad c^2 = .5528$

C = .7436 x 3 = 2.2308

Average = 17.5 + 2.2308 = 19.73

$\sigma = \sqrt{\frac{\Sigma FD^2}{N} - c^2}$

$\sigma = \sqrt{\frac{603}{39} - .5528} \times 3 = 11.57$

19.73 Boys
15.47 Girls
4.26 Diff

$\sigma = \frac{\sigma dis}{\sqrt{N}}$

$\sigma \text{ diff} = \sqrt{\sigma^2 av1 + \sigma^2 av2}$

$\sigma \text{ diff} = \sqrt{(1.85)^2 + (1.17)^2} - 2.19$

G.A. = 14.5

$c = \frac{12}{37} = .3243 \quad c^2 = .1052$

C = .3243 x3 = .9729

Average = 14.5 +.9729 = 15.47

$\sigma = \sqrt{\frac{\Sigma FD^2}{N} - c^2}$

$\sigma = \sqrt{\frac{214}{37} - .1052} \times 3 = 7.15$

$\text{Boys } \sigma \text{ av} = \frac{11.57}{\sqrt{39}} = 1.85$

$\text{Girls } \sigma \text{ av} = \frac{7.15}{\sqrt{37}} = 1.17$

TABLE LI

Grade VII

Comparison of City and Country Scores

Boys

	No. of Cases	Average Score	σdis
Country	38	16.63	10.72
City	39	19.73	11.57

$$\begin{array}{rr} \text{City} = & 19.73 \\ \text{Country} = & \underline{16.63} \\ & -3.10 \end{array}$$

$$\sigma\text{av} = \frac{\sigma\text{dis}}{\sqrt{N}}$$

$$\text{Country } \sigma\text{av} = \frac{10.72}{\sqrt{38}} = 1.74$$

$$\text{City } \sigma\text{av} = \frac{11.57}{\sqrt{39}} = 1.85$$

$$\sigma\text{ diff} = \sqrt{\sigma^2\text{avl} + \sigma^2\text{av2}}$$

$$\sigma\text{diff} = \sqrt{(1.74)^2 + (1.85)^2} = 2.54$$

Girls

	No.of Cases	Average Score	σdis
Country	33	11.5	7.38
City	37	15.47	7.15

$$\begin{array}{rr} \text{City} = & 15.47 \\ \text{Country} = & \underline{11.5} \\ & 3.97 \end{array}$$

$$\sigma\text{av} = \frac{\sigma\text{dis}}{\sqrt{N}}$$

$$\text{Country } \sigma\text{av} = \frac{7.38}{\sqrt{33}} = 1.28$$

$$\text{City } \sigma\text{ av} = \frac{7.15}{\sqrt{37}} = 1.17$$

$$\sigma\text{diff} = \sqrt{\sigma^2\text{avl} + \sigma^2\text{av2}}$$

$$\sigma\text{diff} = \sqrt{(1.28)^2 + (1.17)^2}$$

$$\sigma\text{diff} = 1.73$$

TABLE LII
ORDER OF DIFFICULTY

CORRECTED SCORES

BOYS AND GIRLS

NUMBER	QUESTION NUMBER	PER CENT
1	2	95.2
2	11	88.2
3	115	87.7
4	18	82.2
5	19	81.2
6	113	83.0
7	62	80.5
8	40	78.0
9	128	77.5
10	39	77.1
11	7	77.0
12	191	76.5
13	134	76.1
14	104	76.0
15	144	75.2
16	101	75.0
17	182	74.9
18	44	74.7
19	15	72.6
20	87	72.6
21	107	72.5
22	46	72.4
23	42	71.6
24	64	70.8
25	9	69.1
26	10	68.4
27	148	68.3
28	106	68.0
29	105	66.4
30	38	66.4
31	49	66.2
32	140	66.1
33	8	66.0
34	37	65.3
35	94	65.3
36	32	65.1
37	130	65.0
38	47	64.5
39	208	63.7
40	68	63.6
41	85	62.7
42	31	62.3
43	119	62.1
44	79	62.0
45	171	61.1
46	224	61.1
47	1	60.9
48	116	60.9
49	97	60.0

NUMBERS	QUESTION NUMBER	PER CENT
50	58	59.8
51	143	59.1
52	120	58.6
53	13	58.1
54	227	57.8
55	33	57.7
56	55	57.6
57	59	57.5
58	129	57.4
59	226	57.4
60	51	57.0
61	77	56.7
62	153	56.7
63	189	56.6
64	278	56.1
65	117	55.8
66	80	55.4
67	149	55.5
68	222	55.0
69	20	54.9
70	219	54.9
71	187	54.8
72	12	54.7
73	111	54.6
74	112	54.5
75	169	54.5
76	56	54.4
77	162	53.5
78	194	53.2
79	274	53.0
80	214	52.9
81	91	52.7
82	138	52.7
83	67	52.8
84	70	52.5
85	50	52.5
86	74	52.4
87	168	52.3
88	4	52.2
89	190	52.2
90	98	52.1
91	207	52.0
92	225	51.5
93	151	51.2
94	25	51.0
95	133	51.0
96	72	50.5
97	185	50.5
98	88	50.3
99	199	49.9
100	23	49.5
101	181	49.2
102	53	49.1
103	275	48.4
104	206	48.2

NUMBERS	QUESTION NUMBER	PER CENT
105	197	47.8
106	54	47.7
107	235	47.7
108	218	47.4
109	127	46.8
110	142	46.7
111	81	46.5
112	126	46.2
113	71	45.8
114	223	45.4
115	221	45.2
116	66	45.0
117	100	45.0
118	135	44.8
119	217	44.2
120	26	43.7
121	246	43.8
122	84	43.7
123	272	43.0
124	21	42.8
125	215	42.5
126	114	42.3
127	178	42.0
128	76	41.7
129	41	41.7
130	3	41.6
131	36	41.5
132	156	41.5
133	131	41.1
134	108	40.8
135	202	40.8
136	28	40.7
137	211	40.7
138	167	40.6
139	276	40.4
140	282	40.1
141	198	40.2
142	146	40.0
143	188	39.5
144	29	39.3
145	30	39.3
146	209	39.2
147	78	39.0
148	24	38.4
149	154	38.5
150	110	38.1
151	152	38.1
152	141	37.6
153	232	37.5
154	65	37.3
155	48	37.2
156	203	37.2
157	86	37.1
158	123	36.9
159	166	36.6
160	230	36.4
161	14	36.3
162	6	36.2

NUMBERS	QUESTION NUMBER	PER CENT
163	52	35.3
164	122	34.8
165	89	34.7
166	228	34.3
167	102	33.9
168	277	33.9
169	27	33.8
170	212	32.6
171	241	32.5
172	160	32.1
173	73	32.0
174	137	31.6
175	259	31.6
176	249	31.5
177	90	31.1
178	132	31.1
179	229	31.1
180	92	31.0
181	139	31.0
182	159	31.0
183	35	30.9
184	155	30.5
185	242	30.4
186	69	30.4
187	99	30.3
188	157	30.1
189	261	29.9
190	63	29.8
191	75	29.5
192	96	29.4
193	82	29.3
194	179	29.2
195	95	29.1
196	124	28.8
197	192	28.8
198	61	28.5
199	204	28.5
200	287	28.5
201	118	28.2
202	172	28.2
203	258	27.7
204	161	27.1
205	193	26.8
206	34	26.6
207	289	26.4
208	125	26.2
209	245	25.8
210	186	25.6
211	260	24.8
212	236	24.3
213	254	24.3
214	57	24.2
215	291	23.9
216	295	23.8
217	263	23.5
218	158	23.4
219	234	22.8
220	184	22.7

NUMBERS	QUESTION NUMBER	PER CENT
221	22	22.7
223	170	22.4
224	60	22.4
225	290	22.0
226	109	21.9
227	45	21.8
228	147	21.6
229	145	21.5
230	264	21.3
231	300	21.3
232	200	21.0
233	17	20.9
234	174	20.8
235	164	20.7
236	243	20.7
237	297	19.5
238	285	19.4
239	299	19.3
240	16	19.2
241	173	19.1
242	251	18.8
243	257	18.7
244	262	18.7
245	238	18.4
246	165	18.3
247	205	18.3
248	195	18.0
249	248	17.4
250	267	16.9
251	180	16.7
252	237	16.6
253	239	16.3
254	183	15.8
255	93	15.8
256	271	15.4
257	294	15.3
258	252	15.2
259	292	15.2
260	5	15.1
261	175	15.1
262	268	15.1
263	121	14.8
264	293	14.7
265	163	14.4
266	273	13.9
267	240	13.5
268	176	13.3
269	266	13.2
270	216	13.1
271	288	12.9
272	136	12.7
273	265	12.5
274	43	12.2
275	210	12.1
276	298	12.1
277	256	12.0
278	284	12.0

NUMBERS	QUESTION NUMBER	PER CENT
279	253	11.9
280	233	11.8
281	231	11.5
282	255	11.4
283	270	11.3
284	247	11.2
285	196	11.0
286	150	10.9
287	213	10.7
288	286	10.6
289	250	10.4
290	201	10.1
291	281	10.0
292	279	9.4
293	296	9.4
294	103	9.1
295	283	7.7
296	177	7.3
297	280	7.3
298	83	6.1
299	269	6.1
300	220	4.7

TABLE LIII

ORDER OF DIFFICULTY

BOYS

Number	Question Number	Per Cent
1	2	93.9
2	115	93.9
3	11	87.6
4	19	86.0
5	16	85.5
6	40	84.5
7	62	84.5
8	144	84.3
9	113	83.7
10	46	82.9
11	128	81.9
12	191	80.4
13	134	79.9
14	39	79.6
15	44	79.0
16	107	78.8
17	87	78.7
18	101	78.6
19	18	78.3
20	182	77.8
21	68	77.2
22	32	76.7
23	42	76.4
24	47	75.8
25	64	74.8

TABLE LIII

ORDER OF DIFFICULTY

BOYS

Number	Question Number	Per Cent
26	148	74.8
27	130	74.4
28	79	74.2
29	104	74.1
30	15	73.9
31	7	73.8
32	116	73.8
33	105	73.1
34	8	72.5
35	106	71.4
36	10	71.3
37	58	71.1
38	1	70.9
39	208	70.8
40	143	70.7
41	49	70.4
42	94	69.7
43	119	69.4
44	31	68.0
45	13	67.9
46	224	67.5
47	129	67.3
48	162	67.3
49	226	67.3
50	85	66.9

TABLE LIII

ORDER OF DIFFICULTY

BOYS

Number	Question Number	Per Cent
51	140	66.7
52	12	66.2
53	189	66.1
54	38	64.8
55	51	64.9
56	185	64.6
57	56	64.1
58	72	64.0
59	77	63.9
60	80	63.4
61	151	63.2
62	227	62.3
63	59	62.2
64	112	62.0
65	111	61.8
66	133	61.8
67	117	61.7
68	153	61.7
69	25	61.5
70	222	60.8
71	67	60.7
72	74	60.6
73	278	60.5
74	81	60.3
75	149	60.1

TABLE LIII

ORDER OF DIFFICULTY

BOYS

Number	Question Number	Per Cent
76	171	60.0
77	70	59.6
78	48	59.3
79	225	59.3
80	169	59.0
81	274	59.0
82	168	58.8
83	207	58.6
84	9	58.5
85	91	57.7
86	197	57.7
87	55	57.6
88	98	57.6
89	138	57.6
90	53	57.5
91	190	57.3
92	37	56.8
93	135	56.8
94	4	56.5
95	194	56.5
96	142	55.8
97	108	55.6
98	218	55.6
99	20	55.5
100	126	55.5

TABLE LIII

ORDER OF DIFFICULTY

BOYS

Number	Question Number	Per Cent
101	54	55.4
102	181	55.4
103	97	55.3
104	114	55.1
105	36	54.8
106	219	54.4
107	21	54.1
108	88	53.9
109	127	53.7
110	110	53.4
111	199	53.4
112	41	53.1
113	214	52.9
114	206	52.8
115	120	52.7
116	14	52.5
117	211	52.3
118	26	51.5
119	71	51.1
120	50	50.9
121	86	50.9
122	235	50.8
123	215	50.6
124	275	50.6
125	217	50.2

TABLE LIII

ORDER OF DIFFICULTY

BOYS

Number	Question Number	Per Cent
126	26	49.9
127	30	49.5
128	66	49.4
129	187	49.4
130	52	49.1
131	282	48.5
132	246	48.1
133	167	47.5
134	272	46.8
135	65	46.6
136	100	46.6
137	137	46.5
138	84	46.4
139	156	46.3
140	178	46.3
141	154	46.2
142	28	45.6
143	221	45.4
144	141	44.4
145	203	44.2
146	121	44.0
147	6	43.9
148	276	43.9
149	123	43.7
150	3	43.5

TABLE LIII

ORDER OF DIFFICULTY

BOYS

Number	Question Number	Per Cent
151	76	43.4
152	209	42.7
153	223	42.7
154	89	42.6
155	166	42.5
156	192	42.3
157	78	42.1
158	24	41.9
159	146	41.7
160	159	41.4
161	249	40.5
162	122	40.3
163	73	40.0
164	63	39.8
165	232	39.7
166	277	38.8
167	75	38.6
168	198	38.6
169	230	38.5
170	118	38.2
171	82	38.1
172	132	37.9
173	152	37.3
174	259	37.1
175	188	37.0

TABLE LIII

ORDER OF DIFFICULTY

BOYS

Number	Question Number	Per Cent
176	212	36.7
177	155	36.6
178	29	36.5
179	99	36.5
180	179	35.7
181	228	35.6
182	90	35.0
183	102	35.0
184	124	34.9
185	139	34.8
186	241	34.8
187	204	34.3
188	202	33.9
189	96	33.5
190	260	33.3
191	261	32.9
192	35	32.8
193	157	32.6
194	193	31.7
195	92	30.9
196	95	30.9
197	287	30.9
198	69	30.7
199	27	30.3
200	258	30.1

TABLE LIII

ORDER OF DIFFICULTY

BOYS

Number	Question Number	Per Cent
201	16	29.8
202	45	29.5
203	172	29.5
204	229	29.3
205	158	29.0
206	242	28.8
207	160	28.5
208	34	28.3
209	289	27.8
210	125	27.5
211	161	27.0
212	61	26.7
213	263	26.6
214	236	26.2
215	254	25.6
216	184	25.0
217	186	25.0
218	245	24.7
219	195	24.5
220	57	24.3
221	290	23.6
222	244	23.4
223	17	23.1
224	93	23.1
225	243	22.9

TABLE LIII

ORDER OF DIFFICULTY

BOYS

Number	Question Number	Per Cent
226	291	22.7
227	170	22.4
228	165	22.2
229	200	22.2
230	145	22.1
231	205	21.7
232	147	21.2
233	174	21.0
234	234	21.0
235	297	20.4
236	60	20.2
237	239	19.9
238	262	19.7
239	299	19.3
240	5	19.0
241	271	18.9
242	285	18.8
243	251	18.7
244	248	18.6
245	257	18.6
246	183	18.5
247	264	18.3
248	237	18.1
249	267	18.1
250	268	17.8

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TABLE LIII

ORDER OF DIFFICULTY

BOYS

Number	Question Number	Per Cent
251	300	17.7
252	292	17.2
253	164	17.0
254	216	16.9
255	238	16.9
256	247	16.7
257	180	16.3
258	109	16.2
259	288	16.0
260	265	15.5
261	210	15.3
262	273	15.3
263	150	15.2
264	175	15.2
265	270	15.1
266	231	15.0
267	121	14.7
268	286	14.6
269	294	14.6
270	43	14.5
271	163	14.5
272	253	14.5
273	240	14.3
274	196	14.2
275	298	13.9

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TABLE LVII

ORDER OF DIFFICULTY

BOYS

Number	Question Number	Per Cent
276	293	13.8
277	173	13.3
278	256	13.1
279	176	13.0
280	252	13.0
281	295	31.0
282	266	12.4
283	250	11.9
284	296	11.7
285	255	11.6
286	136	11.3
287	281	11.1
288	279	10.7
289	284	10.7
290	22	9.8
291	103	9.7
292	213	9.7
293	283	8.7
294	233	8.6
295	201	7.6
296	177	7.5
297	280	7.4
298	269	6.3
299	83	5.6
300	220	5.1

TABLE LIV

ORDER OF DIFFICULTY

GIRLS

Number	Question	Per Cent
1	2	96.5
2	11	88.7
3	115	84.1
4	113	82.3
5	7	80.1
6	9	79.6
7	18	78.9
8	104	77.8
9	62	76.5
10	19	76.3
11	39	74.6
12	37	73.7
13	128	73.1
14	191	72.6
15	134	72.2
16	182	72.0
17	40	71.5
18	15	71.3
19	44	70.3
20	38	69.8
21	42	66.8
22	64	66.7
23	87	66.3
24	107	66.2
25	144	66.1

TABLE LIV

ORDER OF DIFFICULTY

GIRLS

Number	Question Number	Per Cent
26	10	65.5
27	140	65.5
28	97	64.7
29	106	64.5
30	120	64.5
31	171	62.1
32	49	62.0
33	46	61.9
34	148	61.8
35	101	71.4
36	94	60.9
37	187	60.1
38	105	59.6
39	8	59.4
40	85	58.5
41	55	57.6
42	208	56.6
43	31	56.5
44	33	55.9
45	130	55.6
46	219	55.3
47	119	54.7
48	224	54.6
49	32	54.5
50	20	54.1

TABLE LIV

ORDER OF DIFFICULTY

GIRLS

Number	Question Number	Per Cent
51	50	54.0
52	227	53.3
53	47	53.1
54	214	52.9
55	59	52.7
56	153	51.7
57	278	51.6
58	149	50.8
59	1	50.8
60	23	50.7
61	68	50.0
62	169	50.0
63	194	49.9
64	79	49.8
65	117	49.8
66	77	49.4
67	222	49.2
68	51	49.0
69	58	48.5
70	13	48.3
71	223	48.1
72	116	47.9
73	4	47.8
74	138	47.8
75	91	47.7

TABLE LIV

ORDER OF DIFFICULTY

GIRLS

Number	Question Number	Per Cent
76	129	47.5
77	143	47.4
78	226	47.4
79	111	47.3
80	80	47.3
81	112	47.0
82	189	47.0
83	274	46.9
84	88	46.6
85	190	46.6
86	98	46.5
87	199	46.4
88	275	46.2
89	168	45.7
90	207	45.4
91	70	45.3
92	221	44.9
93	67	44.8
94	56	44.7
95	235	44.5
96	74	44.2
97	225	43.7
98	206	43.5
99	100	43.3
100	12	43.2

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TABLE LIV

ORDER OF DIFFICULTY

GIRLS

Number	Question Number	Per Cent
101	181	43.0
102	29	42.1
103	188	42.0
104	198	41.6
105	76	40.9
106	84	40.9
107	202	40.7
108	108	40.7
109	66	40.5
110	71	40.4
111	25	40.4
112	133	40.1
113	162	39.7
114	3	39.6
115	54	39.4
116	151	39.1
117	246	39.1
118	218	39.1
119	146	38.3
120	217	38.2
121	131	38.1
122	197	37.9
123	142	37.6
124	178	37.6
125	272	37.3

TABLE LIV

ORDER OF DIFFICULTY

GIRLS

Number	Question Number	Per Cent
126	27	37.3
127	276	36.9
128	72	36.9
129	126	36.8
130	156	36.7
131	185	36.4
132	78	35.9
133	28	35.8
134	26	35.8
135	24	34.8
136	209	35.7
137	160	35.6
138	22	35.5
139	232	35.3
140	215	34.4
141	230	34.2
142	21	34.2
143	167	33.7
144	228	33.0
145	102	32.8
146	135	32.8
147	229	32.8
148	81	32.6
149	242	31.9
150	282	31.6

TABLE LIV

ORDER OF DIFFICULTY

GIRLS

Number	Question Number	Per Cent
151	241	31.0
152	192	31.0
153	154	30.8
154	141	30.7
155	166	30.6
156	61	30.3
157	203	30.2
158	41	30.2
159	123	30.1
160	69	30.1
161	145	20.9
162	127	29.8
163	114	29.4
164	122	29.2
165	30	29.1
166	211	29.0
167	35	28.9
168	152	38.9
169	277	28.9
170	6	28.5
171	212	28.5
172	243	28.4
173	86	28.2
174	65	27.9
175	109	27.5

TABLE LIV

ORDER OF DIFFICULTY

GIRLS

Number	Question Number	Per Cent
176	157	27.5
177	95	27.2
178	90	27.1
179	161	27.1
180	139	27.1
181	172	26.9
182	245	26.8
183	261	26.8
184	89	26.8
185	186	26.1
186	287	26.0
187	259	26.0
188	270	26.0
189	258	25.3
190	96	25.3
191	291	25.1
192	289	25.0
193	173	24.9
194	34	24.8
195	300	24.8
196	234	24.6
197	60	24.5
198	132	24.3
199	155	24.3
200	164	24.3

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TABLE LIV

ORDER OF DIFFICULTY

GIRLS

Number	Question Number	Per Cent
201	264	24.3
202	57	24.1
203	73	24.0
204	99	24.0
205	125	24.9
206	86	23.3
207	254	22.9
208	110	22.7
209	124	22.7
210	179	22.7
211	204	22.6
212	170	22.6
213	249	22.5
214	236	22.3
215	147	21.9
216	244	21.8
217	193	21.8
218	52	21.4
219	159	20.5
220	174	20.5
221	82	20.4
222	184	20.4
223	290	20.4
224	263	20.3
225	75	20.3

TABLE LIV

ORDER OF DIFFICULTY

GIRLS

Number	Question Number	Per Cent
226	14	20.0
227	238	19.9
228	285	19.9
229	63	19.7
230	200	19.7
231	299	19.2
232	251	18.9
233	17	18.7
234	257	18.7
235	297	18.5
236	118	18.2
237	158	17.7
238	262	17.7
239	252	17.3
240	180	17.1
241	137	16.7
242	295	16.5
243	260	16.3
244	248	16.2
245	294	16.0
246	267	15.7
247	293	15.5
248	92	15.2
249	48	15.1
250	175	15.0

TABLE LIV

ORDER OF DIFFICULTY

GIRLS

Number	Question Number	Per Cent
251	233	15.0
252	237	15.0
253	121	14.9
254	205	14.9
255	165	14.4
256	163	14.2
257	45	14.1
258	136	14.0
259	266	13.9
260	176	13.5
261	284	13.2
262	292	13.1
263	183	13.0
264	240	12.7
265	239	12.6
266	201	12.5
267	273	12.5
268	268	12.3
269	271	11.8
270	213	11.6
271	195	11.5
272	5	11.2
273	255	11.1
274	256	10.9
275	298	10.3

TABLE LIV

ORDER OF DIFFICULTY

GIRLS

Number	Question Number	Per Cent
276	43	9.9
277	288	9.8
278	265	9.5
279	53	9.3
280	216	9.3
281	210	8.9
282	281	8.9
283	250	8.9
284	16	8.6
285	93	8.5
286	103	8.5
287	279	8.1
288	231	8.0
289	196	7.8
290	270	7.4
291	280	7.2
292	296	7.1
293	177	7.0
294	150	6.6
295	283	6.6
296	286	6.6
297	83	6.5
298	269	5.9
299	247	5.6
300	220	4.2

APPENDIX B

OBJECTIVE TEACHING

In 1926 the writer was confronted with the problem of introducing the subject of physics, as an elective for girls, in a large high school. A class of about twenty students was selected and a course outlined. An attempt was made to establish this course in the curriculum by making it very practical. Texts were used only as references and material for the course was taken from the practical experiences of life. A glance at the number electing physics in Table LV will show that at the end of four years, little progress had been made.

Physics is our most fundamental subject in science. The information which it contains is of great use to girls as well as to boys. If properly taught it should prove as fascinating to girls as it is to boys.

Although the writer had taught the subject ,physics, for nineteen years, a study of the situation convinced him that he did not know how to teach physics to girls. To realize that you do not know how to teach is the first great concept necessary for objective teaching. The second principle, which is similar to it, is to know that you do not know what to teach. Objective teaching is impossible for any teacher until he has acquired these two fundamental concepts.

Webster[1] states that the term objective is applied to

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[1] Noah Webster, International Dictionary of the English Language, G.and C.Merriam Company, Springfield, 1906.

TABLE LV

Number Electing Physics

YEAR	Number Electing Physics	Average Achievement	Number of Sections	Total Enrollment	% Electing
1924-1925	0	-	0	1362	0.00
1925-1926	0	-	0	1676	0.00
1926-1927	0	-	0	1847	0.00
1927-1928	20	79.0	1	1964	1.02
1928-1929	29	77.4	1	2542	1.14
1929-1930	30	77.3	1	2833	1.06
1930-1931	20	84.0	1	2901	0.69
1931-1932	69	79.8	2	2942	2.35
1932-1933	65	83.4	2	2984	2.18
1933-1934	75	80.0	2	2957	2.54
1934-1935	81	79.7	3	2146	3.77
1935-1936	31	76.2	1	1986	1.56
1936-1937	101	83.0	3	1856	5.44
1937-1938	96	79.0	3	1679	5.72
1938-1939	108	77.1	4	1704	6.34
1939-1940	160	82.0	5	1755	9.1
1940-1941	158	81.6	5	1743	9.1

things exterior to the mind. An instructor who enters the classroom with his course planned in advance is not in a position to do objective teaching.

The first step which an instructor should take, when meeting his class, is to give an objective test to determine student interest . This test is then followed by an objective test to determine the proper level for the inception of instruction. Many research investigations of concept levels and sex differences must be carried out if inexperienced teachers are to engage in real objective teaching. Here is an opportunity for schools of education to make a real contribution to the educative process. These investigations can be carried out, however, only by those who have been trained to reason inductively in the scientific manner.

In real objective teaching, the goals of the pupil must be temporarily substituted for the more mature goals of the teacher. The successful teacher, in attaining the goals of the pupil, will also succeed in reaching the real goals of the subject, which usually consist of general laws and principles in logical arrangement.

The stern of a ship is the point from which it may be most easily directed. To attempt to hold a boat on its course by forcibly pushing the bow in a certain direction results in wasted time and energy. Instead of telling our students what to do, we should train them so they will be able to show us what should be done.

Valuable time is wasted when students do not study with interest and intent to remember. Wheeler[1] states that the effect of intent to remember was to increase immediate recall 22% and delayed recall 50%.

Thayer[2] says there is danger that adult ideas and adult activities will be imposed upon the child. Education would become static if children simply relived the experiences of others. The teacher should select out of the child's activities those things which are of most importance. The fundamental law is not the student's main objective. He wishes to send a telegraph message or make a motor run. His learning is thus called incidental.[3] It is the duty of the teacher to see that this incidental learning is organized. Wheeler[4] says there are two conditions for effective learning :

1. Perception of a goal.
2. Selecting material or situations sensible to the learner. Bode[5] states that there are other objectives of education

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[1] R.H. Wheeler, The Science of Psychology, T.Y.Crowell Company, New York, 1928, pp.224-243.

[2] V.T. Thayer, The Passing of the Recitation, D.C.Heath and Company, Boston, 1928, pp.259-265.

[3] Boyd H. Bode, Modern Educational Theories, The MacMillan Company, New York, 1927, pp.149-157.

[4] R.H. Wheeler, op. cit., pp.240-255.

[5] Boyd H. Bode, op.cit., Chapter XV.

besides frequency of use. He says that democracy needs a distinctive type of education and that, until this task is achieved, educational reform is bound to mean the destruction of old educational values for the sake of cheap and immediate ends.

Must we not teach children under our control to think accurately and carefully ? Should they not be able to put together observed facts and from these observed facts to reason inductively to a general conclusion even though that conclusion may seem very remote during the period of observation ?

If we cannot prevent the future citizens of this country from arriving at immediate and erroneous conclusions at the suggestion of demagogues and crooked politicians, is not the future of democracy in danger ? If this tendency to clear and accurate inductive thinking cannot be taught in the physics laboratory where we always have the laws of nature to give a correct answer, in what part of our school curriculum can this most important attribute of education be imparted ?

Laboratory work, then, must form a part of an objective teaching program. It is here that the student discovers for himself that there is a real cause for everything. Superstition and chance are banished from his mind.

It would be disastrous for an inexperienced teacher to attempt objective teaching. Before the end of the first week, he would be confronted with so many unknown problems

that he would become discouraged and lose the respect of his class. In order to be master of the situation, he would need experience as a plumber, radio technician, electrician, automobile mechanic, aviator, engineer, etc.

Many teachers now claim that such subjects are too involved for high school students. If the rules of objective teaching are to be followed, instruction should be given in any field which enters the environment of the student. Some teachers say, for instance, that the subject of alternating currents should not be attempted until the student has reached the higher levels. Alternating currents enter the home and may often become a part of the child's first experience in the field of electricity. A method by means of which elementary students may study alternating current electricity has already been outlined.[1]

It is to be regretted that most science teachers are not equipped to teach objectively. Preparation for objective teaching should include a wide knowledge of trade school subjects as well as the theoretical foundation now supplied by colleges. Does not the importance of scientific knowledge in this country make it desirable that a special course for the training of science teachers be introduced by some college or university ?

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[1] R. B. DeLano, Applied Electricity, D.C. Heath and Company, Boston, 1924, pp.115-195.

Principles

of

Objective Teaching

The main steps in objective teaching may be listed as follows:

1. Pupils lead.
2. Teacher follows with a guiding hand on the helm.
3. A new subject should always start with material familiar to the majority of the class.
4. Oral(or written) pretest is always used to determine the starting point.
5. Only those subjects are studied which interest the majority of the class at that particular time.
6. Frequency of use is an important factor in determining the amount of time spent on a given subject.
7. Facts which students can obtain by direct observation are not given by the teacher.
8. Training in scientific observation is emphasized.
9. A new subject is introduced before the majority of the class reaches its stalling point on the subject being discussed.
10. Problems are introduced only after the student recognizes that they are necessary for a proper understanding of the subject.
11. Pupils draw their own conclusions and state their own laws. Teacher acts as guide only.
12. Teacher seldom decides in advance just what he will teach during a given period.
13. Teacher never tries "forced feeding".
14. Artificial motivation is never necessary in real objective teaching.

15. Recitations are usually at their most interesting point when the dismissal bell rings.

16. Teacher realizes that the objectives of a fifteen-year-old child are not the same as those of a forty-year-old scientist.

17. A skillful teacher will fulfill pupil objectives without waste of time.

18. The subject matter presented will vary greatly with each class.

19. The units discussed in objective teaching are not carefully insulated from each other but are correlated and varied like true life experiences.

20. Teacher teaches students rather than subjects.

21. Silent and discussion demonstrations are used. The teacher does little talking.

22. The objective, inductive, integrated method of teaching will probably cause a reduction in the number of units covered but this will be balanced by the fact that each topic covered will be of vital importance to the class as a whole.

23. Consideration is given to sex differences.

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15. Fitzpatrick, F.L., *Science Interests*, Teachers College, Columbia University, New York, 1936, 72 p.

An investigation of the science interests of pupils based upon their own testimony.

16. Garrett, Henry E., *Statistics in Psychology and Education*, Longmans, Green and Company, New York, 1926. XIII - 317.

Chapter I contains a method for obtaining the standard deviation; Chapter IV shows how to obtain a coefficient of correlation, and Chapter VI applies statistical methods to test results.

17. Haupt, George W., *A Philosophy of Science Teaching in an Elementary School*, Teachers'College Contributions to Education, Number 633, Teachers'College,Columbia University, New York, 1935. pp.103-105.

A good illustration of the practical use of the objective type of aim.

18. Haupt, George W., "Generalizations in Elementary School Science", School Science and Mathematics, XXXIV, (June, 1934), pp.574-577.

A discussion of the fact that it is important to ascertain when and how children generalize rather than to know simply that they generalize.

19. Hawkes, H.E., Lindquist, E.F., Mann, C.R., The Construction and Use of Achievement Examinations, Houghton, Mifflin Company, Boston, Massachusetts, 1936. 496 p.

Contains a scholarly discussion of the principles to be used in constructing multiple-choice tests.

20. Heil, Louis M., "Physics in General Education", School Science and Mathematics, XL, (January, 1940). pp.27-35.

A discussion of exceptional merit. Physics should not be made easy. Among the criteria are: physical and mental health, use of leisure time, social responsibility, purchase of goods, and vocational orientation.

21. Hopkins, L. Thomas, Differentiation of Curriculum Practice and Teaching Methods in High Schools, Thirty-fifth Yearbook of the National Society for the Study of Education, Public School Publishing Company, Bloomington, Illinois, 1936.

An analysis of courses of study and teaching methods. Mentions courses which provide differentiation.

22. Hurd, Willis A., "Present Inadequacy and Suggested Remedies in the Teaching of Physics", School Science and Mathematics, XXX, Number 4 (May, 1930). pp.539-546.

Suggests that subject matter should be more suited to pupils, that teachers should have better training, and that pupils should have more responsibility.

23. James, William, Talks to Teachers on Psychology. Henry Holt and Company, New York, 1901. p.95.

"We should begin with the child's native interests and present to him objects that have immediate connection with these."

24. Jessen, Carl A. and Herlihy, Lester B., Offerings and Registrations in High School Subjects, U.S. Office of Education, Bulletin Number 8, Government Printing Office, Washington, D.C., 1938. pp.28-29.

This bulletin consists mainly of lists of registrations in all high school subjects up to 1934.

25. Kefauver, Grayson N., "The Validity of Bases for Forming Ability Groups", Teachers College Record, Number 31, (November, 1929). pp.100-112.

The judgment of teachers in the elementary school is the most important source of information for predicting success in the first year of the high school.

26. Lu Pone, O. J., "Some Problems That Must Be Answered in Elementary Science", School Science and Mathematics, XXXVIII, Number 6 (June,1938).pp.666-672.

"No criteria have been determined for grade placement of topical material."

27. Matteson, H.D. and Kambly, P.E., "Knowledge of Science Possessed by Pupils Entering Seventh Grade", School Science and Mathematics, XL, Number 3 (March,1940). pp.244-247.

A test was administered to 573 pupils entering the seventh grade. It was found that there was little difference between the scores of the pupils who were and those who were not taught general science. The fact that the pupil assumes more knowledge than he actually possesses tends to dull his interest in science.

28. Morrison, Henry C., The Practice of Teaching in the Secondary School, The University of Chicago Press, Chicago, 1931. 688 p.

The importance of understanding the science type of learning is considered in this book.

29. National Education Association, Department of Superintendence, Fifth Yearbook, Washington, D.C., 1927. pp.145-180.

Contains twenty-seven studies in science and a discussion of the aims of science teaching in the junior high school.

30. National Society for the Study of Education, Thirty-first Yearbook, Part I, *A Program for Teaching Science*, Public School Publishing Company, Bloomington, Illinois, 1932. p.42.

A discussion of the objectives of education and the organization of subject matter.

31. Otis, Arthur S., *Statistical Method in Educational Measurement*, World Book Company, Yonkers-on-Hudson, New York, 1925. XI - 337 p.

Chapter VIII contains methods for calculating the standard deviation and Chapter XXI discusses methods for grading and classifying.

32. Peters, J.T., "The Physics Teacher Faces His Problems", *School Science and Mathematics*, XLI, Number 6 (June, 1941) pp.559-567.

We should arrange for different levels of work to meet the preparation and ability levels of pupils. Physics teachers should have both physics courses and methods of teaching in their preparation for high school work. We should accept the challenge and teach physics to the masses.

33. Phillips, M.J.W., "The Pupil-Initiated Project in High School Physics", *School Science and Mathematics*, XLI, Number 4 (April,1941) pp.346-350.

"Modern educational procedure is assumed to take into account the individual interest of the child, to find his interest, and to hold it while he is learning. Science furnishes the teacher many opportunities for this type of work."

34. ________________, "Responsibilities of Teachers with Special Training in Science", *School Science and Mathematics*, XL, Number 8,(November, 1940).pp.738-748.

"Teacher education suffers from the fact that the courses which form its basis are, in substance, those that were originally designed to accomplish the high degree of specialization that is required for research and for work in the scientific professions, especially medicine and engineering, and has not been planned with reference to the teacher's work."

35. Physics Syllabus Committee, Physics Club of New York, "The Teaching of the Scientific Attitude by Means of Selected Topics in Physics", School Science and Mathematics, XLI, Number 8, (November, 1941) pp.740-746.

True learning is regarded as desirable adaptations which take effect in the behavior of the pupil. A development of the scientific attitude, use of the scientific method, an understanding of great generalizations in physics, and an understanding of the applications of physics in the environment of the pupil are considered as desirable adaptations.

36. Powers, Samuel Ralph, "Educational Values of Science Teaching", Teachers College Record, XXXII, (October,1930). pp.17-33.

A theoretical analysis and discussion of the main objectives of science teaching.

37. ____________________, and others, A Program for Teaching Science, Thirty-First Yearbook, Part I, National Society for the Study of Education, Public School Publishing Company, Bloomington, Illinois, 1932. 370 p.

Suggestions for the construction of courses for the teaching of science and recommendations for the setting up of objectives.

38. Progressive Education Association, Commission on Secondary School Curriculum, Science in General Education, D.Appleton-Century Company, Inc., New York, 1939.p.12.

A treatise dealing with methods of teaching and the selection of suitable material.

39. Relyea, G.M., "What Science Articles Do Junior High School Pupils Read?" School Science and Mathematics, XLII, Number 2 (February,1942).pp.181-184.

A study made in Grades VII,VIII,and IX. Aviation and medicine were popular subjects. Influencing factors were the avocational and the vocational interests of children.

40. Ruch, G.M. and Stoddard, G.D., Tests and Measurements in High School Instruction, World Book Company, Yonkers-on-Hudson, New York, 1927. XIX - 379 p.

Chapter XVI contains a discussion of methods used in objective examinations.

41. Rusk, Rogers D., How to Teach Physics, J.B.Lippincott Company, Philadelphia, Pennsylvania, 1923. X-186 p.

Chapter VIII contains a good discussion of practical physics teaching. Chapter XIII points out some of the common mistakes made in the teaching of physics.

42. Sisson, J. C., A Study of the Abilities, Interests and Needs of Sixth-Grade Pupils as an Aid to the Selection of Functional Subject Matter for a Seventh Grade Course in General Science, unpublished Master's Thesis, Boston University School of Education, Boston, 1940, 138 p.

An attempt, by means of a multiple-choice test, to discover subject matter having a functional value for seventh grade pupils.

43. Teller, James D., "How Can Textbooks in High School Physics Help in Guiding Pupils in Scientific Thinking ?" School Science and Mathematics, XLI, Number 1 (January, 1941). pp.49-54.

"To expect students to discover even the major principles of physics in an elementary course would be absurd; to expect them to engage in that type of mental activity from which these principles have resulted is essential if they are to be trained in the method of science.

44. Thayer, V.T., The Passing of the Recitation, D.C.Heath and Company, Boston, 1928. pp.259-265.

Thayer says there is danger that adult ideas and activities may be imposed upon the child. He also states that education will become static if children simply relive the experience of others.

45. Thorndike, E. L., Teacher's Word Book of Twenty Thousand Words, Teachers College, Columbia University, New York, 1931.

In this volume, twenty thousand words are rated for frequency and range.

46. Vanderploeg, E.P., LeCocq,C.L.,Huffman,O.F., The Content of Junior High School Science, Unpublished Masters' Theses, State University of Iowa, Iowa City, Iowa, 1939.

13 textbooks were analyzed in an attempt to ascertain what science material should be taught on the 7th,8th, and 9th grade levels. The conclusions state that there was little agreement among the authors as to what content should be included at the various grade levels.

47. Vordenberg, Kenneth E., "High School Physics for General Education", School Science and Mathematics, XLI, Number 6 (June,1941). pp.548-552.

About 20% of high school students profit from present physics courses. The remaining 80% could get enjoyment and profit from a physics course suitably organized and effectively presented. The educational training of teachers of physics needs strengthening.

48. Wheeler, R. H., The Science of Psychology, T.Y. Crowell Company, New York, 1928. pp.224-243.

Gives the effect of intent to remember on immediate and delayed recall.

49. Zim, Herbert S., "Student Interest in Science", School Science and Mathematics, XLI, Number 4 (April,1941). pp.385-389.

A research investigation, involving five schools in New York, to secure data on student interest in science.

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